VOL. 30, No. 2 JUNE, 1960

INDIAN JOURNAL OF AGRICULTURAL SCIENCE

ISSUED BY
INDIAN COUNCIL OF AGRICULTURAL RESEARCH
NEW DELHI

Annual subscription
Rs. 10·00

Price per copy
Rs. 2·50

Available from
The Business Manager
Indian Council of Agricultural Research
Dr. Rajendra Prasad Road, New Delhi.

INDIAN JOURNAL

OF

AGRICULTURAL SCIENCE

VOL. 30, No. 2 JUNE, 1960

CONTENTS

DEVELOPMENT AND MORPHOLOGY OF *KARAIL* SOILS IN THE LOWER GANGETIC BASIN OF UTTAR PRADESH

R. N. GUPTA, C. L. MEHROTRA and R. R. AGARWAL

Department of Agriculture, Uttar Pradesh, Kanpur

Received : December 7, 1959.

Preliminary investigations on the genesis and chief pedogenic characteristics of *karail* soils occurring in the lower Gangetic basin of Uttar Pradesh were reported by Agarwal *et al.* (1956). Evidence was adduced to show that these soils owe their distinctive characters to the argillaceous parent material supposed to be basaltic in nature and received by the Ganges through its tributaries draining the trap rocks of Bundelkhand. Subsequent detailed soil studies in the contiguous districts of Mirzapur, Varanasi, Ghazipur and Ballia in the eastern Uttar Pradesh have revealed the occurrence of *karail* soils in well defined tracts as zonal formations covering about 0·2 million acres, half of which can be found in Ghazipur district where such soils cover about 10 per cent of the total area. Such significant occurrence is due to vast expanse of low lying riverain tracts on either banks of Ganga which flow in a circuitous route through the heart of the district. *Karail* formation is conspicuous and intense at places where the Ganges makes many loops and turns, whereby the effects of currents are slowed down and the river gets a chance to deposit its load of light and fine earth brought down through its upper tributaries. Since the heavier particles are deposited first, either as fresh alluvium or on older alluvium, a characteristic change in the profile of such deposit is found below a few feet. However, where the deposition is deep, such a change is observed only several feet below. Formations further inland are the results of change in the course of the stream in prehistoric days. At least some such change is visible in many of the *karail* tracts and remnants of old streams of the river can still be seen in the name of Banganga in Chandauli, Gangharnala in Mahamdabad and Burhganga in Zamania tehsils.

The natural vegetation is scarce and consists of scattered shrubs of *kans* (*Saccharum spontaneum*) and *babool* (*Acacia arabica*). The soils are, however, highly fertile and most extensively cultivated. The major problem is one of soil moisture control. Heavy texture and adverse structure limit timely ploughing and tillage operations. Irrigation is practised to a remarkably low extent and major part of the area grows crops under dry farming.

METHODS

Soil profile examination was made *in situ* on sites selected on a four mile grid. Three profiles on each site were examined, representing the most dominant characteristics and typical stages of soil development in the site in question.

Soil samples, sieved through 2 mm. round hole sieve, were utilized for detailed laboratory analysis. Mechanical analysis was done by the International Pipette Method of Robinson (1933). Chemical analyses were carried out following the methods

outlined by Piper (1950). Organic carbon was determined by the method given by Walkley and Black (1934) and total nitrogen by a modified Kjeldahl's method. Clay was separated and analysed through fusion with sodium carbonate as given by Wright (1939). Free iron oxide was determined in the clay separates by treatment with hydrogen peroxide by the method of Drosdoff and Troug (1935). Exchangeable calcium and magnesium were determined by Hissink's method (1923) and exchange capacity by leaching with ammonium acetate.

OBSERVATIONS

The soils have been numbered serially as *karail* Types 1 to 4. Soil type in this paper refers to the genetic type and is not used in the sense in which it is understood in soil survey operations. They also fall in the same sequence of maturity and help to illustrate the process of development of *karail* soils as a separate soil family in the Gangetic basin of Uttar Pradesh, with a characteristically different parent material of alluvial origin.

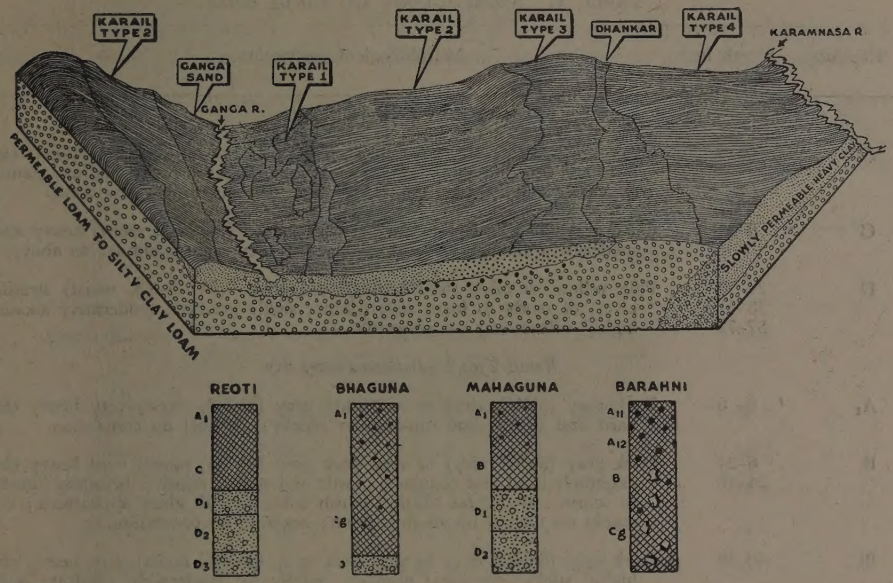
Site characteristics and Morphology (Table 1)

(a) *Karail Type* 1 was sampled from village Reotipur, two miles south of river Ganga in its flood plain. The profile is not deep and is normally underlaid by a bed of sand; but the sequence of horizons is quite often uncertain. The profile may be differentiated into a dark gray clayey surface layer only about plough depth which is un-developed followed by a subsurface or subsoil of the same colour and texture. Stratification is commonly seen.

(b) *Karail Type* 2, which is most extensively distributed soil in the whole family, was sampled from village Bahaguna in Ghazipur district. The entire landscape gets submerged during rains leading to soil formation under highly humid conditions. The deposition of the parent material had also occurred under negligible currents. The profile is, therefore, characterised by a uniform dark gray colour and heavy clay texture with highly plastic and sticky structure. In some cases, the parent material is almost entirely clay. Excess of lime has all been leached to substratum layers. The profile is generally moderately deep to sometimes very deep.

(c) *Karail Type* 3 occupies slightly elevated spot in the same landscape and, therefore, escapes submergence during rains. It is comparatively lighter in texture and eluviation of some clay is also perceptible.

(d) *Karail Type* 4 was located from village Barahni of Varanasi district and is the relatively mature type of soil formation in the upland depressions. The profile is characterised by a dark gray to grayish brown colour with occasional thin surface horizon of light clay followed by a thicker subsurface horizon of the same texture. Below it is usually a deep subsoil horizon of medium to heavy clay. The structural B-horizon, as well as the translocation of clay, is relatively very prominent. Iron-manganese nodules are more common in the upper layers. Calcareous nodules are common in the subsoils which are richer in lime, magnesia, manganese and phosphates than any of the calcareous concretions in associated soil types (Gupta, 1955).



TOPOGRAPHIC RELATIONSHIP AND PROFILE CHARACTERISTICS OF *KARAIL* SOILS.

Mechanical composition

In Table II are summarised the results of mechanical analyses of the four types of *karail* soils. *Karail* soils, like any other alluvial soils, are low in coarse sand fraction and unlike all other alluvial soils of the Indo-Gangetic basin are excessively rich in clay. Silt plus clay in *karail* Type 1 constitutes about 80 per cent of the soil material. Below 24 inches is the stratified layer of sand. The proportion of clay increases in Type 2 soils where clay alone accounts for 80 per cent of the soil. In *karail* Type 3, there is slight increase in coarse sand. The contents of silt and clay are the same as in type 1 but there is more eluviation of clay. In *karail* Type 4, the translocation of clay is more gradual, but there is significant increase in the proportion of coarse sand.

Chemical composition

In Tables III and IV are summarised the data of chemical composition of the total soil and in Tables V and VI, the composition of the clay separates and the derived molecular ratios. *Karail* Type 1 soils are rich in lime, magnesia and phosphates. Except for lime, alkalies and alkaline earths are concentrated in the upper horizons. Nitrogen and organic matter are also adequate. The soils are moderately alkaline. *Karail* Type 2 is less supplied with bases as compared to Type 1. Excess of lime has been leached out. The contents of nitrogen and organic matter have decreased and

TABLE I. MORPHOLOGY OF *KARAIL* SOILS

Horizon	Depth in inches	Morphological description
		Karail Type 1—*Reoti light clay*
A_1c	0– 5 &	Olive gray (5Y5/2-4/2, dry) to dark grayish brown (2·5Y4/2, moist) clay; hard and firm; breaking into very fine subangular blocky to medium granular structure; mildly alkaline; calcareous; no concretion; few roots.
C	5–24	Olive gray (5Y5/2, dry) to dark grayish brown (2·5Y4/2, moist) heavy sclay; moderately alkaline and calcareous; in other respects similar to above.
D	24–38 38–57 57–72	Pale yellow to olive (5Y7/3, dry) and olive (5Y5/3-4/3, moist) stratified layers of sandy to loam soil; friable; single grained; moderately alkaline; highly calcareous; no concretions.
		Karail Type 2—*Bahaguna heavy clay*
A_1	0– 6	Dark gray (5Y4/1, dry) to very dark gray (5Y3/1, moist) very heavy clay; hard and sticky; fine sub-angular blocky; neutral; no concretion.
B	6–24 24–40	Dark gray (5Y4/1, dry) to very dark gray (5Y3/1, moist) very heavy clay; extremely hard and compact; plastic and sticky; massive, breaking into fine to coarse sub-angular blocky; bluish coatings with glazy appearance; wide cracks on drying up to this depth; neutral; no concretion.
BC	40–58	Dark gray (5Y4/1, dry) to very dark gray (5Y3/1, moist) very heavy clay; highly sticky, compact; masive; mildly to moderately alkaline; a few specks of lime concretion.
D	58–72	A clear sharply defined horizon of pale olive gray (5Y6/3, moist) clay loam; less compact; massive; moderately alkaline; few small lime nodules.
		N.B. Stickiness and firmness increases in the lower sub-soil; on drying the soil cracks wide and deep enough for the legs to go in.
		Karail Type 3—*Mahaguna medium clay*
A_1	0– 6	Gray (5Y5/1, dry) to dark gray (5Y4/1, moist) medium clay; hard and firm; fine subangular blocky on drying; slightly acidic; no concretion roots of kans.
B	6–28	Dark gray (5Y4/1, dry) to very dark gray (5Y4/1-3/1, moist) heavy clay; plastic and sticky; firm; massive, breaking into blocky peds on drying; neutral; non-calcareous; a few iron nodules present.
CD	28–39 39–60 60–72	Light olive gray (5Y6/2, dry) to olive gray (5Y5/2, moist) stratified layers of clay loam alternated by lighter soil; compact except in mid-layer; massive to single grained; alkalinity increasing with depth; non-calcareous.
		Karail Type 4—*Barahni light clay*
$A_{11}cn$	0– 4	Gray (5Y5/1, dry) to dark gray (5Y4/1, moist) light clay; moderately fine strong sub-angular blocky; compact; plastic and sticky; slightly acidic to neutral; reddish brown stains and rusty streaks on root channels; some iron manganese nodules; non-calcareous; a few snails and organic matter present.
$A_{12}cn$	4–14	Gray (5Y5/1, dry) to very dark gray (5Y3/1, moist) light clay; strong fine sub-angular blocky with definite shiny faces; hard and compact, plastic and sticky; neutral to slightly alkaline; iron nodules more in number.
A_3Bg	14–28 28–40	Gray (5Y5/1, dry) to dark gray (5Y4/0, moist) heavy clay with bluish gray coatings; massive, breaking into strong fine sub-angular blocky; glassy faces; highly compact; sticky; mildly alkaline; a few iron nodules and a few *kankar* nodules and small calcareous shells of animal origin.

TABLE 1. (*Contd.*)

BCg	40–56	Transition horizon of olive gray heavy clay; in other respects similar to above.
	56–72	Olive gray (5Y4/2, dry) to olive or pale olive gray (5Y5/3, to 5Y6/3, moist) heavy clay; sticky and smeary; compact; massive; breaking into coarse blocky peds on drying; slightly alkaline; a few *kankar* nodules; in the original state the soil appears dispersed in marked contrast to upper horizons which have well-defined peds.
		N.B. The soil cracks upto about 40 inches on drying.

TABLE II. MECHANICAL COMPOSITION OF *KARAIL* SOILS

(Per cent oven dry soil)

Depth in inches	Coarse sand	Fine sand	Silt	Clay
		Karail Type 1		
0– 5	0·46	22·0	28·2	49·0
5–24	0·09	19·5	28·5	46·5
24–38	0·07	60·1	15·9	18·4
38–57	0·20	75·9	7·2	13·0
57–72	0·12	58·4	14·9	20·7
		Karail Type 2		
0– 6	0·13	5·0	11·9	81·9
6–24	0·16	4·1	14·5	80·5
24–40	0·21	3·1	13·9	81·6
40–54	0·26	4·0	13·7	80·2
54–72	0·29	39·2	27·7	28·1
		Karail Type 3		
0– 6	0·98	25·5	25·0	49·2
6–28	0·86	18·4	22·5	61·3
28–39	0·58	43·4	24·9	33·3
39–60	0·24	60·0	19·3	20·9
60–72	0·31	24·8	38·2	37·2
		Karail Type 4		
0– 4	2·42	33·1	19·9	44·6
4–14	2·34	32·8	19·7	45·8
14–28	1·79	31·9	19·9	47·0
28–40	1·73	30·8	20·4	46·8
40–56	1·59	27·6	20·3	50·9
56–72	1·40	27·4	21·3	50·0

carbon-nitrogen ratios have slightly increased. The contents of lime register a further decrease in *karail* Type 3 although phosphoric acid and potash are roughly the same. The pH values show a further decline and register a slight increase from acidic to mildly alkaline reaction in the subsoil. *Karail* Type 4 soils are relatively poorest in magnesia, potash and phosphate. This soil type shows leaching of the bases and alluviation in sub-soil, but the position is more or less stabilised. The contents of nitrogen and organic matter are also low and nitrogen needs of crops on this soil will have to be carefully determined.

The chemical composition of the clay fractions (Tables V and VI) is remarkably constant throughout the profile depth in all the four soil types. The clay fraction of *karail* Type 1 is rich in bases particularly in magnesia. Silica and sesquioxides are fairly constant in the profile at $46{\cdot}2 \pm 0{\cdot}2$ and $36{\cdot}75 \pm 0{\cdot}25$ per cents respectively. Both the constituents of sesquioxides behave in the same way. The various molecular ratios are likewise constant in the profile. The base exchange capacity at the surface is 75 milliequivalents per cent and falls off in the stratified layer. *Karail* Type 2 soils show little difference in clay composition from *karail* type 1 soils except that it is slightly more siliceous as is evident from the higher silicatoalumina and silica to sesquioxide ratios. The exchange capacity also slightly increases. Similarly *karail* Type 3 soil is slightly more siliceous than *karail* Type 2 soil, but magnesium appears to have undergone greater weathering in this soil type. There is also some leaching of the free iron oxide. These effects are most pronounced in *karail* Type 4 soils which are relatively mature type of soil formation. The colloidal part appears to have undergone greater weathering and magnesium leaching is quite prominent. Iron oxide has also gone out of the clay and silica to sesquioxides and silica to iron oxide ratios have consequently again increased over other soil types of the catena. Leaching of iron with respect to alumina is also indicated in the greater divergence of alumina to iron oxide ratios in this soil type. The exchange capacity of the clay, however, has shown a significant decrease.

Exchangeable Bases and Base exchange Capacity

Table VII contains the data on exchangeable bases and base exchange capacity of these soils. The exchange capacity of *karail* soils is very high, ranging from 25 to 55 milliequivalents depending upon the amount of clay. These figures undoubtedly indicate the clay fraction to be dominantly rich in 2:1 expanding lattice type of minerals. The soils are for the most part saturated with bases of which exchangeable calcium forms the bulk. The next dominant exchangeable cation is magnesium. It may be as low as 2 m.e. and in some cases as high as 15 m.e., the relative proportion in relation to calcium depending upon the degree of drainage, the hydrologic regime, the nature of weathering and the degree of profile development. A significant fact is the progressive increase of magnesium and sodium saturation with depth at the expense of calcium. In *karail* Type 3 soils, the situation in respect to sodiumisation has improved and calcium saturation again increases. *Karail* Type 4 soils have lowest amount of exchangeable bases, but calcium saturation has again shown a significant increase in preference to magnesium.

TABLE III. CHEMICAL COMPOSITION OF *KARAIL* SOILS

(Per cent oven dry soil)

Depth in inches	HCl insol-ubles	R_2O_3	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O	P_2O_5	CO_2	Loss on ignition
				Karail Type 1						
0– 5	73·66	16·59	9·63	6·96	1·48	2·11	0·56	0·173	0·31	4·26
5–24	70·58	16·37	9·59	6·78	3·70	2·00	0·53	0·134	1·36	4·63
24–38	80·68	8·90	4·84	4·06	4·04	1·32	0·47	0·132	2·75	3·37
38–51	84·52	6·77	3·54	3·23	3·25	1·11	0·34	0·139	2·22	1·67
51–72	80·63	10·00	5·86	4·14	3·92	1·30	0·35	0·140	2·23	2·65
				Karail Type 2						
0– 6	66·21	21·95	13·34	8·61	1·22	2·48	1·35	0·101	0·00	6·53
6–24	64·88	23·26	14·62	8·64	1·22	2·38	1·29	0·088	0·00	6·34
24–40	64·58	21·95	13·45	8·50	1·14	2·52	1·36	0·098	0·00	6·59
40–54	65.09	22·89	14·48	8·41	1·25	2·45	1·46	0·074	0·00	5·93
54–72	74·21	13·69	8·24	5·45	3·53	2·07	0·99	0·013	1·54	2·69
				Karail Type 3						
0– 6	75·75	15·71	9·41	6·30	0·82	1·55	0·98	0·094	0·00	4·63
6–28	72·93	18·12	10·96	7·16	0·92	1·77	1·16	0·092	0·00	4·38
28–39	80·06	13·73	8·23	5·53	0·59	1·49	0·86	0·083	0·00	2·66
39–60	83·75	11·06	6·29	4·77	0·49	1·38	0·72	0·104	0·00	1·93
60–72	74·28	15·71	9·35	6·36	0·81	1·92	1·03	0·093	0·00	2·90
				Karail Type 4						
0– 4	79·48	13·52	8·73	4·79	0·95	0·57	0·84	0·049	0·00	4·45
4–14	78·76	14·66	10·52	4·14	1·00	0·70	1·02	..	0·00	4·01
14–28	78·96	14·13	8·40	5·73	1·10	0·67	0·97	0·082	0·08	4·06
28–40	79·42	13·98	8·89	5·09	1·12	0·74	0·87	0·067	0·13	3·73
40–56	77·49	15·28	9·93	5·35	1·04	0·72	0·96	0·079	0·11	4·13
56–72	78·24	14·42	9·27	5·15	1·11	0·93	1·02	0·085	0·095	3·65

TABLE IV. GENERAL ANALYSES AND DERIVED MOLECULAR RATIOS FROM THE CHEMICAL COMPOSITION OF *KARAIL* SOILS

Horizon	Depth in inches	Organic carbon	Total nitrogen	C:N ratio	pH	$\frac{CaO}{MgO}$	$\frac{MgO}{Al_2O_3}$	$\frac{Al_2O_3}{Fe_2O_3}$
			Karail Type 1					
A_1C	0– 5	0·79	0·088	8·9	7·8	0·50	0·56	2·17
C	5–24	0·43	0·053	8·1	7·9	1·32	0·54	2·21
D	24–38	0·21	0·025	8·4	8·0	2·19	0·69	1·86
	38–57	0·12	0·012	10·0	8·2	2·09	0·79	1·72
	57–72	0·13	0·020	6·5	8·1	2·15	0·56	2·23
			Karail Type 2					
A_1	0– 6	0·51	0·045	11·4	7·0	0·35	0·46	2·43
B	6–24	0·48	0·047	10·2	6·8	0·37	0·42	2·65
	24–40	0·50	0·038	13·1	7·0	0·32	0·48	2·48
BC	40–54	0·42	0·041	10·3	7·8	0·36	0·43	2·70
D	54–72	0·12	0·032	3·9	8·1	1·22	0·64	2·37
			Karail Type 3					
A_1	0– 6	1·26	0·076	16·7	6·1	0·38	0·41	2·34
B	6–28	0·63	0·056	11·3	6·1	0·37	0·41	2·40
CD	28–39	0·37	0·043	8·5	6·6	0·28	0·46	2·34
	39–60	0·27	0·037	7·2	6·9	0·26	0·56	2·07
	60–72	0·26	0·043	6·0	7·6	0·30	0·52	2·31
			Karail Type 4					
A_{11}	0– 4	0·58	0·055	10·5	6·5	1·19	0·15	2·86
A_{12}	4–14	0·24	0·045	5·3	6·7	1·03	0·18	3·99
A_3B	14–28	0·22	0·029	7·5	7·1	1·16	0·20	2·31
	28–40	0·22	0·025	8·8	7·5	1·08	0·20	2·75
	40–56	0·18	0·033	5·6	7·3	1·03	0·18	2·92
BCg	56–72	0·12	0·016	7·3	7·0	0·86	0·26	2·83

TABLE V. CHEMICAL COMPOSITION OF THE CLAY FRACTION OF *KARAIL* SOILS

(Per cent oven-dry 2·0 micron clay, lime free basis)

Depth in inches	SiO_2	R_2O_3	Al_2O_3	Fe_2O_3	TiO_2	MgO	K_2O	Loss on ignition	Free Fe_2O_3
				Karail Type 1					
0– 5	46·38	36·67	25·61	11·06	0·83	3·63	2·47	8·27	3·71
5–24	46·39	36·76	25·12	11·64	0·78	3·61	2·35	8·68	3·95
24–38	46·19	36·62	25·08	11·42	0·72	3·50	2·30	8·67	3·96
38–57	45·99	36·98	25·29	11·69	0·72	3·57	2·30	8·78	4·21
57–72	46·07	35·65	24·02	11·63	0·72	3·55	1·84	9·23	4·20
				Karail Type 2					
0– 6	49·43	37·42	25·11	12·31	0·85	3·25	2·23	7·90	3·60
6–24	48·40	37·79	25·56	12·22	0·77	3·17	2·28	8·22	3·44
24–40	48·35	37·98	26·22	11·78	0·76	3·17	2·00	8·66	4·16
40–54	49·23	36·94	25·11	11·83	0·84	3·07	2·24	8·57	3·76
54–72	48·69	37·62	26·28	11·34	0·75	3·09	2·26	9·06	3·76
				Karail Type 3					
0– 6	49·83	36·50	24·84	11·66	0·52	2·38	2·83	8·32	3·10
6–28	48·24	36·87	24·54	12·33	0·74	2·07	2·75	9·35	3·56
28–39	47·77	37·25	25·25	12·00	0·67	2·83	2·69	9·22	3·76
39–60	47·43	37·15	23·92	13·22	0·63	1·87	2·44	8·94	3·90
60–72	47·93	35·78	22·96	12·82	0·66	1·77	2·23	10·88	3·16
				Karail Type 4					
0– 4	50·31	36·70	26·17	10·54	0·69	1·40	2·57	8·47	2·96
4–14	51·15	36·35	25·60	10·75	0·61	1·34	2·33	8·83	2·35
14–28	50·38	36·62	25·78	10·84	0·61	1·54	2·39	8·99	2·94
28–40	51·03	36·49	25·62	10·87	0·62	1·49	2·16	8·67	2·18
40–56	50·99	36·57	25·91	10·65	0·61	1·63	2·16	8·64	2·46
56–72	50·98	36·50	25·63	10·87	0·60	1·41	2·40	8·21	2·34

TABLE VI. DERIVED MOLECULAR RATIOS OF THE CLAY FRACTION OF *KARAIL* SOILS

Depth in inches	$\frac{S_iO_2}{R_2O_3}$	$\frac{S_iO_2}{Al_2O_3}$	$\frac{S_iO_2}{Fe_2O_3}$	$\frac{Al_2O_3}{Fe_2O_3}$	$\frac{MgO}{Al_2O_3}$	$\frac{K_2O}{Al_2O_3}$	Base exchange camp. me per cent
			Karail Type 1				
0– 5	2·41	3·08	11·18	3·63	0·36	0·105	71
5–24	2·42	3·14	10·62	3·39	0·37	0·101	75
24–38	2·43	3·13	10·78	3·44	0·36	0·100	63
38–51	2·39	3·09	10·49	3·39	0·36	0·100	64
51–72	2·49	32·6	10·56	3·24	0·38	0·083	62
			Karail Type 2				
0– 6	2·55	3·35	10·70	3·20	0·33	0·096	75
6–24	2·47	3·22	10·55	3·28	0·32	0·097	78
24–40	2·45	3·14	11·94	3·49	0·31	0·083	83
40–54	2·56	3·33	11·09	3·33	0·31	0·097	75
54–72	2·47	3·15	11·44	3·63	0·30	0·093	68
			Karail Type 3				
0– 6	2·62	3·41	11·39	3·34	0·24	0·123	70
6–28	2·53	3·34	10·42	3·12	0·22	0·122	71
28–39	2·47	3·22	10·62	3·30	0·19	0·115	64
39–60	2·49	3·37	9·55	2·84	0·19	0·111	62
60–72	2·62	5·55	9·98	2·81	0·20	0·105	63
			Karail Type 4				
0– 4	2·60	3·27	12·73	3·89	0·14	0·106	62
4–14	2·68	3·40	12·69	3·74	0·13	0·099	67
14–28	2·62	3·32	12·40	3·73	0·15	0·101	65
28–40	2·67	3·39	12·50	3·70	0·15	0·091	70
40–56	2·65	3·34	12·76	3·81	0·16	0·091	66
56–72	2·66	3·38	12·51	3·70	0·14	0·101	65

DISCUSSION

A number of important basic considerations regarding the genesis of *karail* soils must be kept in view while discussing the development of these soils in any catenary sequence or as a distinct group of associated zonal soils. One, and perhaps the most important of these, is the nature and amount of colloidal fraction in the parent material. The colloidal fraction in these soils is by and large composed of 2:1 expanding lattice type of minerals which by virtue of high concentration and remarkable physical and chemical properties, dominate over other characters of the parent material. The other important feature is the relatively juvenile nature of these soils. Besides, the depressed topography in which most of the members of the group occur is another factor worth consideration. All these factors hinder the development of horizons or even a well-developed texture profile. Nevertheless, certain features become prominent and some conclusions can be drawn regarding their genesis and development when the soils are arranged in relation to their topographical positions in the catena (*vide* Fig. 1.) *Karail* Type 4 soils, the end member of the group, occupy the highest positions in the otherwise depressions of the geologically uplands and therefore, exhibit maximum maturity with an incipient B horizon, maximum gleization and segregation of lime and iron-manganese concretions. These morphological features are gradually diminished in the descending order of the topo-sequence till the bottomland soils are reached which are young and immature with large reserve of free lime.

The alluvial flatlands are richest in clay because of their geomorphological position. The translocation of clay and the development of a textural and structural B-horizon becomes pronounced with maturity. Coarse sand fraction also increases in the ascending sequence due to greater weathering and segregation of iron and manganese in the form of nodular concretions.

This genetic relationship is more clearly exhibited in the topo-sequence series of *karail* soils when their chemical composition is taken into consideration. Jenny (1941) has suggested and quoted a number of molecular ratios, particularly base to alumina, alkalies to alumina and alkaline earths to alumina ratios to indicate the preferential leaching of the bases with respect to alumina and the degree of profile development. Because of the varying pronounced effects of clay minerals and soil forming processes on the relative mobility of the alkalies and alkaline earth bases in soils (Polynov, 1948), it may become confusing if the ratios of the culmulative bases to alumina or even alkalies or alkaline earths to alumina are only considered. On the other hand, if magnesium is taken into account, the molecular magnesia to alumina ratios give a definite trend of the weathering processes at work. Magnesia to alumina ratios steadily decrease in order from *karail* Type 1 to Type 4 soils indicating the preferential leaching of magnesium over aluminum as soil formation proceeds. Like-wise the progressive increase of alumina to iron oxide ratio in the sequence indicates the leaching of iron also with respect to aluminum. In the soil development processes there is thus a progressive weathering and leaching of magnesium and iron as the end members of the group are reached in the increasing order of maturity. These processes are borne out by the fact that the source material of these soils is dominantly rich in ferro-magnesian minerals. It may further be observed that because of their physio-

TABLE VII. EXCHANGEABLE BASES AND BASE EXCHANGE CAPACITY OF *KARAIL* SOILS

(Per cent oven dry soil)

Depth in inches	Ex. Ca.	Ex. Mg.	Ex. K.	Ex. Na	Base exchange capacity me	Saturation percentage with				Ex. Ca
						Ca	Mg	K	Na	Ex.Mg.
					Karail Type 1					
0– 5	29·00	2·59	0·87	0·44	31·6	88·2	7·9	2·6	1·3	11·19
5–24	29·80	2·58	0·81	0·15	32·2	89·4	7·8	2·4	0·4	11·55
24–38	12·60	0·61	0·49	0·13	13·2	91·1	4·4	3·5	1·0	20·65
38–57	7·80	0·60	0·45	0·25	8·6	85·7	6·8	5·0	2·7	13·00
57–72	13·00	1·02	0·45	0·25	14·3	88·3	6·9	3·1	1·7	12·74
					Karail Type 2					
0– 6	38·59	12·39	1·07	1·46	53·6	72·1	23·2	2·0	2·7	3·11
6–24	38·84	10·04	1·00	3·61	54·00	72·6	18·5	1·9	6·7	3·86
24–40	31·78	14·52	1·20	6·07	54·1	59·3	27·1	2·3	11·3	2·18
40–54	25·26	15·39	1·26	5·98	46·9	52·7	32·2	2·6	12·5	1·64
54–72	11·35	4·64	0·46	3.07	19·2	58·1	23·2	2·4	15·7	2·44
					Karail Type 3					
0– 6	24·71	9·71	0·62	0·46	35·9	69·6	27·4	1·7	1·3	2·54
6–28	28·39	11·90	0·57	0·58	42·0	68·5	28·7	1·4	1·4	2·38
28–39	16·14	6·08	0·44	0·69	23·4	69·1	26·0	1·9	3·0	2·65
39–60	10·50	4·80	0·34	..	15·9	67·0	31·3	2·1	..	2·18
60–72	15·20	7·75	0·26	..	23·2	65·5	33·4	1·1	..	1·96
					Karail Type 4					
0– 4	19·74	5·25	0·81	0·50	26·5	75·0	20·0	3·1	1·9	3·75
4–14	21·86	4·97	0·77	0·59	28·6	76·5	17·6	2·7	2·1	4·40
14–28	22·50	5·27	0·99	0·90	29·6	75·9	17·8	3·3	3·0	4·27
28–40	21·53	6·83	0·95	0·45	28·3	72·3	23·0	3·1	1·6	3·15
40–56	21·45	6·48	0·82	0·71	29·0	72·7	22·0	2·8	2·4	3·31
56–72	19·00	6·54	0·87	0·55	26·1	70·5	24·2	3·2	2·0	2·91

graphic position and age, *karail* Type 4 soils in morphological development stand quite apart from Type 3 and Type 2 soils; the latter two are perhaps closer together in that respect and nearer to type 1 soils. The molecular magnesia to alumina and alumina to iron oxide ratios follow the same trend and the wider divergence may be indicative of the greater maturity of the soil. Considering the movement of lime, the higher humidity prevailing on the flatlands brings about a rapid depletion of this constituent and there is a sudden fall in the lime to magnesia ratio. On the uplands where humidity is least pronounced, lime again gets a chance to accumulate in preference to magnesia but this time as a secondary formation. On the contrary, phosphoric acid leaching is quite regular and very pronounced in Type 4 soils.

As the soil formation in *karail* is dominantly controlled by the colloidal fraction of the parent material, a study of the clay fraction should reveal best the pedo-chemical processes. A review of the clay composition shows that whereas potash figures are more or less constant in the whole development series, magnesia leaching is quite pronounced in ascending the toposequence. Potash to alumina ratios consequently do not show any trend, but magnesia to alumina ratios progressively narrow down as the soil formation proceeds. The leaching of iron, likewise, is indicated by the progressive depletion of clay in free iron contents which is supposed to be the more active part of the colloidal iron. The molecular silica to sesquioxides, silica to alumina, and silica to iron oxide ratios slightly increase in the sequence indicating the leaching of iron and slight accumulation of silica. The clay tends to become slightly more siliceous. Thus as weathering proceeds in the development series of *karail* soils, both iron and magnesium tend to segregate or leach out of the soil profile, a feature which forms an important attribute of the pedogenesis of all black soils either of residual or transported origin (Agarwal and Mukerji, 1946).

The base exchange capacity of all these soils is high. In fact the exchange capacity of the clay fraction in the entire sequence except in the mature formation is well near 80 milliequivalents, indicating the clay to be rich in 2:1 expanding lattice type of clay minerals. Subsequent mineralogical studies on these soils have confirmed these findings. X-ray diffraction analysis gives a strong 001 reflection at 17kX for ethylene glycolated samples. It can be concluded from all these data that the clay minerals in *karail* soils would be dominantly composed of dioctahedral smectites.

The dominant soil characteristics of the whole group of *karail* soils would classify them under some zonal lithomorphic variety of sub-tropical black soils of alluvial origin. It is proposed to place them in the Soil order *Karail* under the above classification.

SUMMARY

The whole group of *karail* soils occurring in the lower Gangetic basin of Uttar Pradesh has been placed under three physiographic divisions, depending upon their position with respect to the Ganges and broad morphological characters of the soil profile. These are bottomland *karail*, flatland *karail*, and upland *karail*. Four soil

types have been reported, representing the model profile from each division to illustrate the entire development series in the said topo-sequence order. The profiles named in order from *karail* Type 1 to Type 4 belonged to Reoti, Bahaguna, Mahaguna and Barahni series. Complete morphology, with mechanical, chemical and physico-chemical data are presented. It has been observed that as weathering and soil formation proceeds in the sequence, magnesium and iron undergo maximum weathering and segregation or leaching. These processes form important attributes to the pedogenesis of *karail* soils. It has been suggested that the soils can be classified under some group of zonal lithomorphic variety of sub-tropical black earths of alluvial origin.

REFERENCES

AGARWAL, R. R., MEHROTRA, C. L. and GUPTA, R. N. 1956. *J. Indian Soc. Soil Sci.* **4**(2): 65-71.
———— and MUKHERJI, P. 1946. *Indian J. agric. Sci.*, 116, 483.
DROSDOFF, M. and TRUOG, E. 1935. *J. Amer. Soc. Agron.* **27**: 312.
GUPTA, R. N. 1955. Ph.D. Thesis, Lucknow University, Lucknow.
———— 1958. *Indian J. agric. Sci.* (In press).
HISSINK, D. J. 1923. *Soil Sci.* **15**: 269.
JENNY, H. 1941. *Factors of Soil Formation.* McGraw Hill Book Co., Inc., New York.
PIPER, C. S. 1950. *Soil and Plant Analysis.* University of Adelaide, Adelaide.
POLYNOV, B. B. 1948. Povhvovedenie, 3-13 (vide *Soils & Fert.* **15**: 95).
ROBINSON, G. W. 1933. *Tech. Commun. Bur. Soil Sci., Harpenden*, **26**.
WALKLEY, A. and BLACK, I. A. 1934. *Soil Sci.* **37**: 29.
WRIGHT, C. H. 1939. *Soil Analysis.* Thomas Murby and Co., London.

DECOMPOSITION OF ORGANIC MATTER

1. MINERALISATION OF ORGANIC NITROGEN AND PHOSPHORUS IN SOIL

B. M. GANGWAR and A. N. PATHAK

Government Agricultural College, Kanpur

Received : December 21, 1959.

The decomposition of organic matter in soil has received much attention. The changes nitrogen and phosphorus undergo in soil have been accepted beyond doubt to be closely associated with the microbial activity of the soil. Micro-organisms utilize carbon compounds as a source of energy and mineralize the organic form of nitrogen and phosphorus in a form readily available to the plant. Organic matter thus, maintains the fertility and productivity of the soil.

The literature available indicates that the availability of reserved soil phosphorus is increased by the addition of organic matter. Although the exact mechanism is not clearly understood, much evidence indicates that organic matter plays a great role in increasing the availability of soil phosphorus. This increased availability may be due to the direct supply of phosphorus through the organic matter and-or direct effect of organic matter on the availability of soil phosphorus. The rate of mineralisation of organic nitrogen and phosphorus at different stages of decomposition of the added material, markedly influences the amount of nitrate-nitrogen and available phosphorus for plant growth at any particular time. Also, the net effect of these microbial transformations is determined to a considerable extent by the amount and nature of phosphorus contained in the organic matter and with varying stages of growth depending upon C/P and C/N ratios as well as on other environmental factors. The increased microbial activity following the addition of organic matter may also enhance the rate of release of native phosphorus.

It has long been observed, almost in all the soils, that available phosphatic materials when added to the soil get converted into the insoluble forms, thereby greatly impairing the availability of fertilizers as plant nutrients. It has now been accepted that soluble forms of phosphorus are better available only for some time but upon aging there is no difference in the availability of organic and inorganic forms. Jensen (1917) emphasized that the addition of organic matter to a soil increases the solubility of both lime and phosphoric acid from 32-100 per cent. Baur (1921), Ramaswami Sivan (1925), Hester (1935) and Fuller and McGeorge (1950) have also observed the beneficial effect of organic matter on the availability of phosphorus in soil. At the same time recent work on phosphoric manuring by Hartley and Greenwood (1933), Copeland and Merkle (1942), Bear *et al.* (1946) and Pierre (1949) has given indications that organic manures are a good source of phosphorus to plants.

Salter and Schollenberger (1939) concluded that the availability of phosphorus to plants from farmyard manure is equal to or in some cases exceeds that applied in

chemical fertilizers. Islam and Elahi (1954) working on waterlogged soils showed an increase in the amount of available phosphorus to a considerable extent by the addition of two per cent green manure. Swenson *et al.* (1949) and Struthers and Sieling (1938) have shown that many organic materials in soils were effective in preventing the precipitation of phosphorus by iron and aluminium between pH3—9. Bray and Dickman (1942), Kiertz (1946) and Bass and Sieling (1950) have observed that certain organic anions are effective in extracting phosphate from soils.

METHODS

Samples of cultivated soil were taken from the students' Instructional Farm, Government Agricultural College, Kanpur and those of Forest soil were taken from the Allen Forest besides the farm. The following treatments, supplying 0·05 and 0·1 per cent nitrogen with the above two soils, were made: sanai, farmyard manure, neem cake, blood meal, and control. Table I gives the chemical composition of the soils and the organic materials used.

TABLE I. NUTRIENT COMPOSITION OF SOILS AND ORGANIC MATERIALS

Samples	Organic per cent carbon	Nitrogen		C/N ratio	Phosphorus		Calcium oxide per cent	pH
		Total N per cent	Nitrate N in p.p.m.		Total P_2O_5 per cent	Available P_2O_5 in p.p.m.		
Cultivated soil	0·320	0·058	8·50	5·5	0·110	63·0	0·728	0·4
Forest soil	0·625	0·126	8·75	5·0	0·124	4·0	3·416	8·3
Sanai	63·500	2·875	..	22·1	0·534	..	..	..
Farm Yard Manure	25·400	0·556	..	46·1	0·175	..	..	..
Neem cake	69·400	5·254	..	13·1	1·056	..	..	..
Blood meal	65·400	10·192	..	6·4	1·256	..	..	..

Forest soil is rich in carbon, nitrogen, and calcium. There is practically little difference in nitrate, carbon and nitrogen ratio and pH of the two soils. Though there is practically not much difference in the total phosphorus content of the two soils, yet their available phosphorus contents show great variation. It is 63 p.p.m. in the cultivated soil against 4 p.p.m. only in the forest soil. Neem cake contains the highest amount of organic matter whereas farmyard manure contains the least. Likewise there is a great variation in the nitrogen content of the different organic sources. Blood meal contains as high as 10·19 per cent total nitrogen whereas farmyard manure contains as low as 0·556 per cent. But the C/N ratio of farmyard manure is the widest and that of blood meal is the lowest, sanai and neem cake come in between. These organic materials also vary in their total phosphorus content.

Organic carbon was determined according to Walkley and Black's method (1934). Standard Kjeldahl's method was followed for total nitrogen determinations as modified by Bal (1925). Nitrate nitrogen was estimated according to Harper's (1924) phenol disulphonic acid method. Total phosphorus was estimated in the hydrochloric acid extract of the soils following A.O.A.C. method. Determination of available phosphorus was made according to Troug's (1930) method, which was estimated colorimetrically using red filter in a Spekker Absorptiometer. Calcium was estimated as calcium exalate in the hydrochloric acid extract following A.O.A.C. method. pH was determined using 1 to 2·5 soil to water ratio by Beckman pH meter.

OBSERVATIONS

From the data given in Table II it is observed that there was considerable reduction in the organic matter content of all the treated soils with the advancement of the period of decomposition which had been the greatest in sanai treated soil and lowest in the farmyard manure treated soil at both the levels of nitrogen. Cultivated soil and forest soil showed similar behaviour. It is also observed that as the decomposition proceeds there is a gradual increase in the total nitrogen content. Sanai treated soil showed the greatest increase of total nitrogen in all the treatments. This may be attributed to the fixation of atmospheric nitrogen in the presence of energy matter. This falls in line with the observation of Wilson (1940), Jensen (1944) and Waksman (1952) under foreign conditions and by Dhar and Mukerji (1936) under Indian conditions.

With the incorporation of organic matter there had been an increase in the C/N ratio practically in all the treatments but the bone meal. The C/N ratio of sanai treated soil was the highest followed by farmyard manure and neem cake. The ratio decreased with the decomposition of organic matter. C/N ratio of the forest soil was slightly lower than the cultivated soil at start which maintained the same level even at the end of the experiment.

The data given in Table III shows a continuous process of nitrification. Sanai and farmyard manure showed the active period of nitrification upto the 30th day, after which it slowed down. But the neem cake and blood meal treated samples showed their vigorous activity even upto 60th day. Blood meal showed greatest nitrification closely followed by the neem cake. This may be attributed to the greater quantity of nitrogenous substance accompanying the available non-nitrogenous organic matter. This falls in line with the observation of Hutchingson and Martin (1934) who observed decrease in nitrate content with the increase of C/N ratio. Faster rate of nitrification in the treated forest soil may be due to better physico-chemical condition of the soil for microbial activity.

The available phosphorus content of the treated soils increased with the period of decomposition. Farmyard manure showed the maximum amount of available phosphorus followed by neem cake. The lower value of available phosphorus in the forest soil may be due to the soil character where phosphorus is mostly in non-available form. This may be correlated with the high calcium content of the forest soil (Table I). As Struthers and Sieling (1950), Swenson *et al.* (1949) have indicated that certain

TABLE II. ORGANIC CARBON AND TOTAL NITROGEN

Treatments	At start			at 30 days			At 60 days			At 90 days		
	C	N	C/N	C	N	C/N	C	N	C/N	C	N	C/N
				Cultivated soil (at 0·05 per cent N level)								
Control	0·320	0·058	5·50	0·312	0·057	5·50	0·310	0·058	5·40	0·307	0·060	5·20
Sanai	1·540	0·113	13·70	0·932	0·119	7·80	0·816	0·121	6·70	0·624	0·123	5·10
Farmyard Manure	1·004	0·112	9·00	0·805	0·115	7·00	0·782	0·118	6·70	0·541	0·119	4·50
Neem cake	0·979	0·108	9·00	0·888	0·109	7·50	0·590	0·112	4·80	0·421	0·114	3·50
Blood meal	0·614	0·113	5·40	0·459	0·115	5·20	0·351	0·116	3·10	0·241	0·119	2·70
				(At 0·1 per cent nitrogen level)								
Sanai	2·760	0·168	14·00	1·582	0·173	9·10	1·328	0·176	7·60	1·092	0·178	6·20
Farmyard manure	1·688	0·164	10·40	1·323	0·167	8·20	1·004	0·168	6·50	0·916	0·173	5·60
Neem cake	1·639	0·158	10·50	1·491	0·160	8·40	0·882	0·163	5·70	0·784	0·165	2·80
Blood meal	0·909	0·168	5·40	0·898	0·171	5·30	0·746	0·173	4·50	0·472	0·174	2·70
				Forest soil (At 0·05 per cent N level)								
Control	0·625	0·126	5·00	0·611	0·126	4·80	0·602	0·126	4·80	0·597	0·127	4·70
Sanai	1·845	0·181	10·20	1·215	0·196	6·50	1·005	0·199	5·10	0·953	0·200	4·50
Farmyard manure	1·309	0·178	9·00	1·067	0·178	6·20	0·927	0·185	5·40	0·752	0·186	4·30
Neem cake	1·284	0·176	8·30	1·072	0·178	5·60	0·827	0·180	4·50	0·712	0·184	3·60
Blood meal	0·947	0·181	5·30	0·744	0·196	5·10	0·675	0·198	3·60	0·484	0·198	2·80
				(At 0·1 per cent N level)								
Sanai	3·065	0·236	13·20	1·863	0·248	7·50	1·742	0·249	6·20	1·562	0·250	5·50
Farmyard manure	1·993	0·228	9·00	1·607	0·242	6·70	1·497	0·246	6·10	1·175	0·248	4·90
Neem cake	1·944	0·226	7·80	1·764	0·228	7·10	1·504	0·230	5·60	1·442	0·234	4·80
Blood meal	1·214	0·236	5·40	1·003	0·246	4·80	0·825	0·248	3·70	0·674	0·265	2·80

TABLE III. PH, AVAILABLE NITROGEN AND PHOSPHORUS CONTENTS OF THE SOIL

Treatments	At start			At 30 days			At 60 days			At 90 days		
	pH	Nitrate nitrogen in p.p.m.	Available phosphorus in p.p.m.	pH	Nitrate nitrogen in p.p.m.	Available phosphorus in p.p.m.	pH	Nitrate nitrogen in p.p.m.	Available phosphorus in p.p.m.	pH	Nitrate nitrogen in p.p.m.	Available phosphorus in p.p.m.
Cultivated soil (*At* 0·05 *per cent nitrogen level*)												
Control	8·40	8·5	63·0	8·40	8·92	68·0	8·35	9·12	69·0	8·40	9·56	90·5
Sanai	8·40	8·5	63·0	8·20	18·75	68·0	8·00	19·00	75·0	8·00	22·00	81·5
Farmyard manure	8·40	8·5	63·0	8·35	17·50	112·0	8·00	17·95	248·0	8·00	18·80	136·0
Neem cake	8·30	8·5	63·0	8·30	22·60	88·0	7·90	26·00	156·0	7·85	27·25	80·0
Blood meal	8·40	8·5	63·0	7·80	14·25	80·0	7·80	33·25	88·0	7·70	35·50	68·0
(*At* 0·1 *per cent nitrogen level*)												
Sanai	8·40	8·5	63·0	8·20	20·25	68·0	8·00	21·00	79·0	8·00	26·00	85·0
Farmyard manure	8·40	8·5	63·0	8·35	23·42	148·0	8·00	23·98	272·0	7·90	24·56	152·0
Neem cake	8·40	8.5	63·0	8·25	9·75	128·0	7·70	27·50	184·0	7·70	31·00	100·0
Blood meal	8·40	8·5	63·0	7·79	26·00	108·0	7·70	36·25	128·0	7·50	37·65	92·0
Forest Soil (*At* 0·05 *per cent nitrogen level*)												
Control	8·30	8·75	4·0	8·25	8·75	3·8	8·30	8·82	3·6	8·30	8·95	3·6
Sanai	8·30	8·75	4·0	8·25	31·25	11·0	8·00	31·75	12·5	8·00	32·29	14·0
Farmyard manure	8·30	8·75	4·0	8·25	23·25	40·0	8·20	24·75	60·0	7·90	25·45	52·0
Neem cake	8·30	8·75	4·0	8·20	24·75	28·0	7·90	31·74	40·0	7·90	32·25	22·0
Blood meal	8·30	8·75	4·0	7·75	27·00	13·0	7·60	41·00	18·0	7·50	42·00	32·0
(*At* 0·1 *per cent nitrogen level*)												
Sanai	8·30	8·75	4·0	8·20	31·50	14·0	8·00	34·50	16·0	8·00	38·75	18·0
Farmyard manure	8·30	8·75	4·0	8·20	23·50	116·0	7·90	36·00	124·0	7.90	27·25	111·0
Neem cake	8·30	8·75	4·0	8·20	26·25	40·0	7·80	37·00	48·0	7·70	38·75	28·0
Blood meal	8·30	8·75	4·0	7·60	27·65	17·0	7·50	43·75	20·0	7·50	45·50	38·0

organic substances, principally the hydroxy organic acids and other substances like humus, etc., are particularly effective in forming the stable complex nucleus with iron and aluminium, affecting the liberation of fixed phosphorus, the increased effect of farmyard manure on the availability of phosphorus as compared to the other treatments may be attributed to the nature of organic matter in it. Organic matter pulls the iron and aluminium away from the phosphate in a manner similar to that as expressed by the following equation.

$$Fe\begin{cases}OH\\OH\\H_2PO_4\end{cases} + \text{Organic substance} \rightarrow Fe\begin{cases}OH + H_2PO_4\\OH\\\text{Organic substance}\end{cases}$$

Recent observation of Dalton *et al.* (1952) shows that organic substances are effective in increasing the availability of soil phosphorus.

pH showed a slight decreasing tendency in all the treatments. This decrease had been the greatest in the blood meal-treated soil.

SUMMARY

The result shows that the C/N ratio of the different organic matter treated soils narrowed down. This decrease was observed the highest with bone meal. At the same time there was an increase in the total nitrogen content of the treatments which was observed in both the soils at both the levels. Blood meal treated samples showed maximum nitrification followed by neem cake and sanai, while farmyard manure gave the least nitrification. On the other hand, farmyard manure showed maximum availability of phosphorus. There was little effect of farmyard and sanai on the pH, but neem cake and blood meal showed a tendency to lower down the pH.

REFERENCES

Bal, D. V. 1925. *J. agric. Sci.* **15**: 454.
Bass, G. B. and Sieling, D. H. 1950. *Soil Sci.* **69**: 269.
Baur, F. C. 1921. *ibid.* **12**: 21.
Bear, F. E., King, W. A. and Bender, C. B. 1946. *Bull. N. J. agric. exp. Sta.* No. 730: 1.
Bray, R. H. and Dickman, S. R. 1942. *Proc. Amer. Soc. Soil Sci.* **6**: 312.
Copeland, O. L. and Merkle, F. G. 1942. *ibid.* **6**: 321.
Dalton, J. D., Russell, G. C. and Sieling, D. H. 1952. *Soil Sci.* **73**: 173.
Dhar, N. R. and Mukerji, S. K. 1936. *Nature.* **138**: 1068.
Fuller, W. H. and McGeorge 1950. *Soil Sci.* **70**: 441.
Harper, H. J. 1942. *Proc. Amer. Soc. Soil Sci.* **6**.
Hartley, K. T. and Greenwood, M. 1933. *Emp. J. Exp. Agric.* **1**: 113.
Hester, J. B. 1935. *Soil Sci.* **39**: 247.
Hutchingson, I. G. and Martin, T. L. 1934. *J. Amer. Soc. Agron.* **26**: 333.
Islam, M. A. and Elahi, M. A. 1954. *J. agric. Sci.* **45**: 1-2.
Jensen, H. L. 1917. *J. agric. Res.* **9**: 253.
———— 1944. *Aust. J. Sci.* **6**: 162.
Kiertz, T. 1946. *Soil Sci.* **61**: 111.
Pierre, W. H. 1949. *ibid.* **68**: 185.
Ramaswami Sivan 1925. *Mem. Dep. Agric. India chem. Ser.* **7**: 145.
Salter, R. M. and Schollenberger, C. J. 1939. *Bull. Ohio. agric. exp. Sta.* No. 605:1.
Struthers, P. H. and Sieling, D. H. 1938. *Soil Sci.* **45**: 467.
———— and ———— 1950. *ibid.* **69**: 205.
Swenson, R. M., Cole, C. V. and Sieling, D. H. 1949. *Soil Sci.* **67**: 3.
Troug, E. 1930. *J. Amer. Soc. Agron.* **22**: 874.
Waksman, S. A. 1952. *Soil Microb.* 95.
Walkley, A. and Black, I. A. 1934. *Soil Sci.* **37**: 29.
Wilson, P. W. 1940. *The Biochemistry of Symbiotic nitrogen Fixation.* Madison. Wisconsin.

MICROFLORA OF SOME INDIAN SOILS AS STUDIED BY ENRICHMENT CULTURE METHODS

S. R. KHAMBATA[1], V. IYER[2], RAJUL V. IYER[2], MAYA G. BHAT and J. V. BHAT

Indian Institute of Science, Bangalore 12

Received : November 4, 1959.

In the limited studies that have been undertaken so far on the microbiology of Indian soils, routine media and methods have been extensively employed. Though the value of enrichment culture methods is now widely acknowledged, they have not so far been exploited to considerable extent in the analysis and survey of Indian soils. Essentially, such methods are based on the principle of providing elective conditions for the growth of desired physiological type of microorganisms while not favouring the growth of others. When exploited to the full extent, such methods should, therefore, provide a useful picture of the various physiologically active microorganisms that make up the soil microflora. As part of some recent investigations on Indian soils, a broadbased quantitative and qualitative analysis of the physiologically active groups of microorganisms was undertaken by using the enrichment culture methods. The results of these investigations are presented in this paper.

MATERIAL AND METHODS

Collection and maintenance of soil samples : During the three soil sampling trips A, B and C, 21, 25 and 27 samples were collected respectively from different parts of peninsular India. A composite of 60 well-spaced borings at 20 points in a selected area constituted a sample. Only the top 6 in. of soil comprising the "A" horizon were collected with aseptic precautions in sterile cloth-lined paper envelopes and sealed with adhesive cellophane tape. On reaching the laboratory they were transferred to sterile screw-capped bottles and maintained in a wooden cabinet at 30° C. Usually the samples were analysed within the shortest possible time after reaching the laboratory.

Enrichment culture media : The basal medium to which 0·05 per cent ammonium sulphate was added (where necessary) as a nitrogen source, had the following composition (Table I).

The elective substrates used in these studies were carefully chosen taking into consideration the wide spectrum of carbon and nitrogen compounds present in soil and were incorporated in the basal medium in 0·5 per cent amounts.

The carbon sources used while working with 46 samples from the A and B trips were: cellulose (filter paper strips were used), pectin, starch, glucose, fructose, glycerol, citrate and oleate. Asparagine, urate and hippurate were also used and individually they served as sources of both carbon and nitrogen. Cellulose, pectin and starch were

Present address : 1. Tata-Fison, Bombay
2. S. B. Garda College, Navsari.

TABLE I. COMPOSITION OF BASAL MEDIUM

Components	Concentration
Neutral phosphate mixture ($Na_2HPO_4+KH_2PO_4$)	1·0 g.
NaCl	0·05 g.
$MgSO_4.7H_2O$	0·50 g.
$FeSO_4.7H_2O$	0·0025 g.
$CaSO_4.2H_4O$ (saturated solution)	5·0 ml.
Micronutrient solution	1·0 ml.
Distilled water	1·0 litre
Micronutrient solution:	
$ZnSO_4.7H_2O$	11·0 g.
$MnSO_4.H_2O$	5·0 g.
C_4SO_4	0·05 g.
H_3BO_3	0·05 g.
Na_2MoO_4	2·0 g.
$CuSO_4.5H_2O$	0·007 g.
Distilled water	1·0 litre

selected because they constitute the important plant polysaccharides found in soil; the monosaccharides glucose and fructose were selected, because they are the more important hydrolytic products of polysaccharides; glycerol, because it is an important product of fat hydrolysis and an easily utilisable alcohol; citrate, because of its key role in the Krebs cycle and carbohydrate metabolism; oleate, because it is the most commonly occurring fatty acid. The selection of asparagine was based on its role in transamination and synthesis of other amino acids and in the nutrition and metabolism of microorganisms; urate and hippurate were selected because they are important constituents of bird and animal excreta.

For the remaining 27 soils from the C trip, benzoate, glycine, sucrose, i-inositol, and glutamate were the enrichments set up in place of cellulose, pectin, glucose, fructose, glycerol, urate and asparagine. This change was to find out whether it would result in enriching different types of microorganisms. Sucrose replaced glucose and fructose. Glycine (0·2 per cent) and benzoic acid (0·1 per cent), the decomposition products of hippuric acid, were set up along with hippurate. Inositol being an important product of phytin degradation and glutamate because of its importance in amino acid metabolism were also used as substrates.

The final pH after autoclaving, of each of the tubed enrichments was adjusted to 7·0-7·2.

Incubation and enrichment: Each enrichment medium was inoculated with a few milligrams of soil and the tubes incubated in a slanting position so as to allow maximum aeration at room temperature (24-27°C.). Two successive transfers in the respective liquid media in tubes were effected before planting out the growth on the corresponding agarified media.

Identification of isolates: The colonies from each of the enrichments were isolated in pure culture and studied as per the methods laid down by the Society of American Bacteriologists (1946). Similarly, the actinomycetes and moulds were studied by methods suggested by Skinner *et al.* (1947) and Smith (1946). Most of the microorganisms were identified upto their genera, and in the case of bacteria and Actinomycetes the classification in Bergey's Manual (Breed *et al.*, 1948) was followed.

Utilization of substrates: The isolates were tested for their ability to utilise their enriching substrates. This was judged by their ability to grow in the enrichment medium containing the specific substrate as compared to their inability to do so in the basal medium in absence of the substrate.

Enumeration of physiological groups: The " extinction dilution " method was used for enumerating the various physiological groups of microorganisms using the enrichment media described above.

OBSERVATIONS

Microbial types encountered in various enrichment media: In Table II are enumerated the details with respect to the soils used for inoculating the enrichment media. The microbial types encountered in the different enrichments set up are summarized in Tables III and IV.

TABLE II. STRUCTURE, COLOUR AND REACTIONS OF THE SOILS EXAMINED

Soil types	Place & No. of samples	pH and Colour*
Sandy loam	Coimbatore, 6	8·5, 8·4 Reddish brown 5YR 4/3
		8·2, 8·2, 8·4 Dark reddish brown 5YR 3/4
		8·4, Reddish brown 5YR 4/4
	Mudukkarai, 1	8·5, Yellowish red 5YR 5/6
	Nagore, 1	6·8, Dark grey brown 10YR 4/2
	Kasargod, 1	5·5, Brown to dark brown 7·5 YR 4/4
	Begumpet, 1	7·7, Reddish brown 5YR 4/4
	Bijapur, 1	8·0, Dark brown 10YR 4/3
	Ernakulum, 1	7·5, Greyish brown 10YR 5/2
	Kayangulum, 1	6·2, Brown 10YR 5/3
	Trivandrum, 1	6·9, Light brown 7·5 YR 5/4

TABLE II. (*Contd.*)

Soil type	Place & No. of samples	pH and Colour*
	Pamban, 1	8·5, Light grey 10YR 7/2
	Chinglepet, 1	8·8, Dark brown 10YR 4/3
Sandy	Cannanore, 1	6·9, Yellowish brown 10YR 5/6
	Kasargod, 1	5·4, Reddish brown 5YR 4/4
	Bezwada, 1	7·6, Dark reddish brown 5YR 3/4
	Kandulapalam, 1	6·5, Brown to dark brown 10YR 4/3
	Nira, 1	9·1, Dark grey brown 10YR 4/2
	Near Poona, 1	8·2, Dark yellowish brown 10YR 3/4
	Coimbatore, 2	8·2, Reddish brown 5YR 4/4; 8·2 dark reddish brown 5YR 3/4
	Trichinopoly, 1	8·0, Yellowish red 5YR 4/8
	Mysore, 1	6·6, Brown 7·5 YR 5/4
	Salem, 1	8·2, Dark grey brown 10YR 4/2
	Coimbatore, 1	8·2, Dark reddish brown 5YR 3/3
	Ramnad, 2	8·0, Very dark brown 10YR 2/2
Loam		5·0, Dark brown 10YR 3/3
	Calicut, 2	6·0, Strong brown 7·5 YR 5/6
		5·5, Reddish brown 5YR 5/4
	Mulki, 1	5·2, Red 2·5 YR 4/6
	Moodabidri, 1	5·0, Brown to dark brown 10YR 4/3
	Bangalore, 1	7·7, Yellowish red 5YR 4/6
	Dharwar, 1	6·6, Dark reddish brown 5YR, 3/4
	Karjat, 1	6·2, Brown to dark brown 7·5 YR 4/4
	Anand, 1	8·1, Dark brown 7·5 YR 4/4
	Hotgi, 1	7·8, Very dark grey brown 10YR 3/2
	Kayangulum, 1	5·5, Dark reddish brown 5YR 3/3
	Kesavaram, 1	8·2, Dark brown 7·5 YR 4/4
Silty loam	Dawaleswaram, 1	7·5, Dark brown 10YR 4/3
	Near Poona, 1	8·4, Dark brown 7·5 YR 3/2
	Kayangulum, 2	5·2, Brown to dark brown 7.5 YR 4/4
		3·0, Very dark grey 10YR 3/1
	Viruduhunagar, 1	8·1, Very dark grey 10YR 3/1

TABLE II. (*Contd.*)

Soil type	Place & No. of samples	pH and Colour*
	Madura, 1	8·6, Dark brown 10YR 3/3
	Trichinopoly, 1	7·6, Dark grey brown 10YR 4/2
	Nanjanagud, 1	8·4, Dark grey brown 10YR 4/2
	Tiruvarur, 1	7·7, Dark brown 10YR 4/3
	Cuddalore, 1	7·5, Very dark grey brown 10YR 3/2
Clayey loam	Ootacamund, 1	5·9, Dark reddish brown 5YR 3/4
	Calicut, 1	5·3, Yellowish brown 10YR 5/4
	Bangalore, 1	6·6, Olive brown 2·5 Y 4/4
	Wardha, 1	8·0, Dark yellowish brown 10YR 3/4
	Nira, 1	7·8, Very dark grey brown 10YR 3/2
	Anand, 1	7·4, Brown to dark brown 10YR 4/3
	Near Poona, 2	8·5, Dark brown 7·5 YR 3/2, 8·1 Dark brown 7·5 YR 3/2
	Coimbatore, 1	8·1, Dark brown 10YR 4/3
	Tanjore, 1	6·8, Dark brown 10YR 4/3
	Tinnevelly, 1	5·6, Dark grey brown 10YR 4/2
	Moodabidri, 1	5·5, Dark grey brown 10YR 3/3
	Mangalore, 1	5·3, Dark brown 10YR 5/3
	Wardha, 1	8·2, Dark grey brown 2·5 Y 4/2
	Bezwada, 1	7·8, Dark brown 7·5 YR 3/2
Clayey	Bellary, 1	8·8, Dark grey 10YR 4/1
	Dharwar, 1	7·4, Dark grey brown 10YR 4/2
	Bassein, 1	8·4, Dark grey brown 10YR 4/2
	Broach, 1	7·9, Dark grey brown 10YR 4/2
	Adoni, 1	8·7, Grey brown 2·5 Y 5/2
	Near Poona, 2	7·9, Dark reddish brown 5YR 3/2, 8·6 very dark grey 5YR 3/1

*Colour standard as per Munsell Soil Color Chart, 1954, Munsell Color Co., Inc., Baltimore, Md.

TABLE III. TYPES OF MICROORGANISMS ENCOUNTERED IN VARIOUS ENRICHMENT MEDIA INOCULATED WITH SOIL

Soil No.	Soil type	Cellulose	Starch	Pectin	Glucose	Fructose	Glycerol	Sodium citrate	Sodium oleate	Sodium urate	Sodium hippurate	Asparagine
A 9	Sandy	P.,F.	B.	P.,F.	P.	P.,F.	P.	P.	P.	P.	P.	P.
A 13	Do	P.,Alc.	B.	P.,B.	P.	UB.	P.	P.	P.	P.,B.	P.	P.
A 14	Do	P.,Fus.	B.	B.	P.,B.,UM	P.	P.	P.	P.	P.,B.	P.	P.
B 6	Do	Mould resembling *Alternaria*	Cor.	B.	Cor.	*	P.	*	F.,Asp.	B.	Ach.	*
B 11	Do	Pen	*	B.	B.,Stp.	B.	P.,B.	P.	P.,Asp.	P.	*	*
B 17	Do	—	*	B.	*	UY.	P.	*	P.,Asp.	B.	F.	Cor.
B 18	Do	Pen	*	B.	P.	*	Cor.	P.	P.,Asp.,Pen.	B.	*	Ach.
A 1	Sandy loam	F.,Alc., Noc.	B.	P.,F.,B.	B.	B.	P.	P.	P.	B.	P.,Alc., UB.	P.,Alc.
A 2	Do	P.,F.	B.	P.,F.,B.	B.	B.	P.	P.	P.	B.	P.,UB.	P.
A 3	Do	P.,F.,Alc.	B.	P.,F.,B.	F.,B.	B.	P.,F.	P.	P.	B.,Stp.	P.	P.
A 4	Do	P.	B.	P.,F.,B.	B.	F.	P.,F.	P.,M.	P.,M.	B.	P.	P.
A 5	Do	P.,F.,Alc., Noc.	B.	P.,F.,B.	F.,B.	F.	P.	P.	P.,M.	P.,B.	P.,Alc.	Alc.
B 2	Do	—	*	B.	F.	F.,UY.	B.	P.	Asp.	B.	Alc.	Ach.
B. 4	Do	—	*	B.	P.	F.	F.,B.	*	—	P.	*	Ach.,Cor.
B 8	Do	P.,Stp.	*	B.	B.	B.	B.	*	Asp.	B.	Cor.,Noc.	Cor.
B 19	Do	—	*	B.	*	UY.	P.	P.	P.,Asp.	B.	*	Ach.
A 7	Loam	P.	P.,B.	P.,F.	P.,UM.	P.	P.,F.	P.	P.	P.	P.	P.
A 8	Do	P.,F.,UB.	B.	P.,F.	P.,B.	B.	P.	UB.	P.	P.,B.	—	P.

TABLE III. (*Contd.*)

Soil No	Soil type	Cellulose	Starch	Pectin	Glucose	Fructose	Glycerol	Sodium citrate	Sodium oleate	Sodium urate	Sodium hippurate	Asparagine
A 18	Do	P.,F.,Alc. B.	B.	P.,F.	P.,B.	B.	F.	P.	P.	P.	P.	P.
A 20	Do	P.,F.	P.	P.,F.	P.	F.,B.,Asp.	P.	P.	P.	P.	P.	P.
B 1	Do	UM.	*	P.	P.	Asp.	P.	P.	Asp.	P.	*	*
B 3	Do	UM.	*	B.	B.	B.	B.,Cor.	P.	P.,Asp.	B.	Alc.,Noc.	Cor.
B 7	Do	—	B.	B.	B.	—	P.	*	P.,Asp.	B.	F.	Ach.
B 13	Do	—	Fus.	B.	P.	*	Cor.	P.	UM.	P.	Cor.	Ach.
B 15	Do	—	*	P.,F.	P.	*	B.,UM.	*	P.,Asp.	B.	*	Ach.
B 16	Do	Pen.	Cor.,UM.	P.	*	*	*	P.	P.	B.	Alc.	*
B 20	Do	Pen.	*	B.	*	*	Cor.	P.	P.,UM.	B.	*	*
B 22	Do	Asp.	*	P.	B.	B.	Cor.	P.	*	B.	*	Ach.
B 24	Do	P.,Stp., Fus.	B.	P.,B.	F.	*	B.,Cor.	P.	—	B.	Alc.	*
A 10	Silty loam	P.	P.,UB.	UM.	P.	P.	P.,UY.	P.	P.,Pen.	B.	P.	P.
A 11	Clayey loam	P.,UB.	P.	F.	P.	P.	P.,F.	P.	P.,Pen.	P.	P.	P.
A 12	Do	B.	*	P.	P.	Mould resembling *Monilia*	Asp.	UM.	B.,UM.	P.	P.	UM.
A 15	Do	P.	P.,B.	P.,F.	P.	B.	P.	P.	P.	P.	P.,UB.	B.
A 16	Do	Alc.,Stp.	B.	B.	P.	F.,B.	P.	P.	P.,F.	B.	P.	B.
A 17	Do	P.,F.	B.	P.,B.,F.	UM.	P.,Pen., Mould resembling *Monilia*	P.,F.,Pen.	—	P.	P.	P.	P.

TABLE III. (*Contd.*)

Soil No.	Soil type	Cellulose	Starch	Pectin	Glucose	Fructose	Glycerol	Sodium citrate	Sodium oleate	Sodium urate	Sodium hippurate	Asparagine
A 21	Do	P.	B.	P.,F.	P.	P.	P.	P.	P.,Asp.	P.	P.	P.
B 9	Do	Pen.	Cor.	B.	Cor.	F.	B.	*	P.,Pen.	B.	Alc.	*
B 10	Do	Pen.	Cor.	P.	*	UY.	*	*	Asp.	B.	*	Ach.
B 12	Do	—	Cor.	B.	UM.	F.	Cor.	P.	P.,UM.	—	*	Ach.
B 14	Do	—	Mould resembling *Alternaria*	B.	UM.	F.	B.	*	P.,Pen.	B.	Ach.	Cor.
B 25	Do	UM.	*	P.	P.,B.	UY.	P.	P.	—	B.	*	*
A 6	Clayey	P.	P.,B.	P.,F.	P.	B.,F.	—	P.	P.	P.	P.,UB.	P.
A 19	Do	P.,F.	P.,B.	P.,F.	P.	P.	P.	P.	P.	P.	P.	Alc.
B 5	Do	Pen.	*	P.	UM.	B.,F.,Pen.	P.	P.	P.	B.	*	*
B 21	Do	Fus.	Pen.	P.	P.	UY.	B.,UM.	P.	UM.	B.	*	Cor.
B 23	Do	UM.	B.	B.	—	*	B.	P.	P.,Asp.	B.	Cor.,Noc.	Ach.

Key to the Abbreviations and Symbols used in the Tables 2 and 3

P. =*Pseudomonas*
F. =*Flavobacterium*
Alc. =*Alcaligenes*
Ach. =*Achromobacter*
B. =Bacillus
C. =*Corynebacterium*
Cor. =Coryneform bacterium
A. =*Aerobacter*
Par. =*Paracolobactrum*
M. =*Micrococcus*
Noc. =*Nocardia*
Stp. =*Streptomyces*
Paec. =*Paecilomyces*
Pen. =*Penicillium*
Asp. =*Aspergillus*
Fus. =*Fusarium*
Muc. =Mucor
* =Enriched isolate failed to utilse the substrate subsequently and was therefore discarded.
— =No isolate was enriched
UB. =Unidentified bacterium
UM. =Unidentified mould
UY. =Unidentified yeast

TABLE IV. TYPES OF MICROORGANISMS ENCOUNTERED IN VARIOUS ENRICHMENT MEDIA INOCULATED WITH SOIL

Soil No.	Soil type	Sodium benzoate	Sodium citrate	Sodium glutamate	Glycine	Sodium hippurate	Inositol	Sodium oleate	Sucrose	Starch
C 4	Sandy	P.	P.	P.	P., Cor.	P.	P., Pen.	P.	P., A., Par.	P.
C 7	Do	P.	P.	P.	P.	P.	P., Asp., Paec.	P., UM.	A., Par.	P.
C 13	Do	P.	UB.	P.	P.	P.	P.	P.	A., Par.	P.
C 22	Do	P.	P.	P.	Cor.	P.	P., Fus.	P., Asp.	A., Muc., UM.	P., UM.
C 1	Sandy loam	—	P.	P.	Cor.	P.	P., Pen.	P., Asp.	Par.	P., Stp.
C 19	Do	—	P.	P.	C., Cor.	P.	P., Stp.	P., Asp.	P.	P.
C 10	Loam	—	P.	P.	P.	P.	P., Stp.	P.	A., Par.	P.
C 14	Do	P.	P.	P.	Cor.	P.	P.	P., Pen., UM.	P., A.	P.
C 16	Do	Stp.	P.	P.	C., Cor.	P.	P., Asp.	P., Asp.	A.	F., Mould resembling *Alternaria*
C 20	Do	P.	P.	Ach.	P.	P.	P., Stp.	P., UM.	A.	P., Stp. Mould resembling *Alternaria*
C 6	Silty loam	—	P.	P.	P.	P.	P., Pen.	P.	A.	—
C 8	Do	—	P.	P.	P.	P.	P., Pen.	P.	P., A., Par.	P.
C 24	Do	P.	P.	P.	P.	P.	P., Fus.	P.	P., A., Fus.	P.
C 3	Clayey loam	P.	P.	P.	P.	P.	P., Pen., Asp.	P., Asp. UM.	P., A.	P.
C 12	Do	—	P.	P.	C.	P.	P., Fus.	P.	A.	P.
C 17	Do	P.	P.	P.	C.	P., Mould resembling *Fusarium*	P., Stp., Fus.	P.	A.	P., Stp.

TABLE IV. (*Contd.*)

Soil No.	Soil type	Sodium benzoate	Sodium citrate	Sodium glutamate	Glycine	Sodium hippurate	Inositol	Sodium oleate	Sucrose	Starch
C 23	Do	P.	P.	P.	P.	P.	P.	P., Asp.	UY.	P.
C 26	Do	P.	P.	P.	P., Cor.	P.	P., Fus.	P.	A., UM.	P.
C 2	Clayey	P.	P., Noc.	P.	P.	P.	P., Asp.	P.	P., A.	P.
C 5	Do	P.	P.	P.	P.	P.	P., Asp.	P., Asp.	P., A.	P.
C 9	Do	P.	P.	P.	Cor.	P.	P., Pen.	P.	P., A., Par.	P.
C 11	Do	P.	P.	P.	P.	P.	P., Pen.	P.	A., Par.	P., Stp.
C 15	Do	Asp.	Noc.	B.	—	P.	P., Pen., Asp.	P., B., Asp.	A.	B., Pen.
C 18	Do	—	P., Noc.	P.	P.	P.	P.	P., Asp.	A.	P., Stp., Pen., UM.
C 21	Do	Asp.	P.	P.	Cor.	P.	P., Stp., Pen.	P.	A.	Stp., UM.
C 25	Do	P.	P.	P.	Cor.	P.	P.	P., Asp.	P., UM.	P.
C 27	Do	P.	P.	P.	P., C.	P.	P.	P.	P., UM.	P.

Cellulose was found to enrich mainly *Pseudomonads*, flavobacteria and moulds, the latter being isolated only from sandy, loamy, clayey loam and clayey soils.

Pectin enriched *Pseudomonads* and flavobacteria from all soil types except the one silty loam studied. The genus *Bacillus* was found to occur more frequently in the coarser sandy and sandy loam soils than in those with finer texture. Three of the *Pseudomonas* strains were found to quantitatively decompose pectin (5·4, 6·3 and 17·3 per cent was found to have been utilized) in 48 hours, the pectin having been estimated by a method described by Potter and McCoy (1952).

Starch hydrolysis was mainly found to be due to *Pseudomonas* and *Bacillus* in most of the soil types studied, the less important organisms being Coryneform bacteria, *Streptomycetes* and moulds.

Glucose enrichment yielded *Pseudomonas* from all soil types except the sandy loams. The less frequently encountered *Bacillus* was absent from the silty loam and clayey soils.

Fructose was readily attacked by Flavobacterium, *Bacillus* and *Pseudomonas*, besides a few yeasts and moulds.

Glycerol was found to enrich *Pseudomonas* from all soil types and spore-forming bacilli from all except the silty loam. Flavobacterium was restricted to soils of intermediate texture, viz. sandy loams, loams and clayey loams. Coryneform bacteria were frequently found to occur in loamy soils.

Citrate seemed to exclusively favour the enrichment of *Pseudomonas*.

Oleate decomposition in all the soil types was mainly brought about by *Pseudomonas*, *Aspergillus* and *Penicillium*.

Urate enriched the genus *Bacillus* more readily than *Pseudomonas* and both genera were found in all the soil types studied.

Hippurate was decomposed most frequently by *Pseudomonas*, the less important organisms associated with the breakdown of this substrate being *Achromobacter* sp., Coryneform bacteria and *Nocardia*.

Asparagine likewise, enriched *Pseudomonas*, *Achromobacter* and Coryneform bacteria (in order of frequency of occurrence) from all soil types except the silty loam which was found to have only *Pseudomonas*.

Benzoate revealed *Pseudomonas* to be the dominant organism in all types of soil except the sandy loam.

Glutamate breakdown was brought about almost exclusively by *Pseudomonas*.

Glycine favoured the growth of Corynebacteria (which includes the genus *Corynebacterium* and the coryneform bacteria) and *Pseudomonas*. The frequency of occurrence of both was about the same in sandy, loam, clayey loam and clayey soils. The sandy loams exclusively yielded Corynebacteria whereas the silty loams exclusively yielded *Pseudomonas*.

Inositol was degraded by Pseudomonads and fungi (*Penicillium* and *Aspergillus*) and were found to occur in all soil types studied. *Fusaria* and *Streptomyces* sp. were less frequently isolated.

Sucrose was the only substrate enriching *Aerobacter* and *Paracolobactrum* (genera belonging to the tribe *Escherichieae*) the former being more often enriched than the latter. A few Pseudomonads and moulds were also isolated but these appear to play a less important role in sucrose breakdown than the *Escherichieae*.

Number of physiological groups of microorganisms present in soil: A few soils representing each soil type collected were analysed. The results are presented in Table V. It is at once obvious that the number of physiologically active organisms present in a soil is not correlated with soil structure. Starch, pectin, glucose, urate, hippurate and asparagine (and glycerol only in loams, clayey loams and clays) were found to encourage the growth of large numbers of microorganisms. This indicates the rapidity with which these substrates would undergo degradation in nature as compared to cellulose which comparatively very few organisms are capable of attacking, whereas fructose, glycerol, sodium citrate and sodium oleate occupy an intermediate position.

DISCUSSION

The fate of several naturally occurring organic substances in soil has been demonstrated by use of enrichment culture methods. It became obvious that a few genera of bacteria dominate over others owing to their biochemical abilities. The genus *Pseudomonas* at once stands out as a versatile goup capable of readily attacking almost all the substrates (except sucrose) studied irrespective of the soil type in which it occurs. Urate decomposition in soils seems to be better accomplished by *Bacillus* than by *Pseudomonas*. Besides readily decomposing organic matter, some soil Pseudomonads are known to produce polysaccharides which play an important part in the cementing of soil particles.

In the case of pectin, it appears that the type of pectinolytic organism depends on the soil type. The sandy and sandy loam soils harboured greater number of pectinolytic sporeforming bacilli than soils of finer structure in which *Pseudomonas* and Flavobacteria were commonly found. The quantitative utilization of pure pectin by cultures of *Pseudomonas* is of interest in that relatively few claims regarding pectin decomposition by microorganisms have been supported by chemical evidence and what is more, Pseudomonads had not been associated in the process until recently (Betrabet and Bhat, 1958).

The least understood group of soil bacteria, viz., the Coryneform bacteria have, so far, not been ascribed any particular role in soil. The frequent isolation of these organisms from glycine and to a lesser extent from asparagine (Khambata and Bhat, 1955), glycerol, starch, glucose and hippurate enrichments certainly implicate the Coryneforms in the biological transformation of these substrates in soil.

Moulds belonging to the genera *Aspergillus* and *Penicillium* are important entities responsible for the breakdown of inositol and oleate.

It was significant that sucrose was the only substrate which was found to enrich members of the *Enterobacteriaceae* family, viz., *Aerobacter* and *Paracolobactrum.*

The number of physiologically active groups of microorganisms associated with the decomposition of various substrates tested were not correlated with the soil types used.

SUMMARY

A general survey of the microflora of 73 soils collected from various parts of peninsular India has been carried out by using enrichment culture methods.

TABLE V. NUMBERS OF PHYSIOLOGICALLY ACTIVE GROUPS OF MICROORGANISMS ENCOUNTERED IN VARIOUS SOILS

Soil No.	Soil type	Soil pH	Cellulose	Starch	Pectin	Glucose	Fructose	Glycerol	Sodium citrate	Sodium oleate	Sodium urate	Sodium hippurate	Asparagine
A 13	Sandy	6·2	10^4	$>10^{12}$	10^8	10^{10}	10^6	10^9	10^6	10^6	10^6	10^6	10^9
A 14	Do	6·9	10^4	10^{10}	$>10^{12}$	10^8	10^9	10^6	10^4	10^5	10^9	10^7	10^8
B 6	Do	8·5	10^3	10^6	10^{12}	10^6	10^6	10^5	10^5	10^4	10^5	10^4	10^9
B 11	Do	8·8	10^{12}	10^9	10^{12}	10^8	10^8	10^{11}	10^7	10^5	10^{11}	10^6	10^{10}
B 17	Do	6·9	10^5	10^7	10^{11}	10^7	10^7	10^5	10^6	10^5	10^7	10^8	10^{11}
C 4	Do	7·6	10^3	10^{10}	10^6	10^{11}	10^{11}	10^9	10^7	10^{11}	10^7	10^7	$>10^{12}$
C 7	Do	6·5	10^5	10^{11}	10^8	10^{11}	$>10^{12}$	10^7	10^6	10^{11}	10^6	10^7	$>10^{12}$
C 13	Do	9·1	$<10^6$	10^6	$>10^{12}$	10^8	10^6	10^7	10^5	10^5	10^6	10^7	10^9
C 22	Do	8·2	10^3	$>10^{12}$	10^8	10^8	10^7	10^8	10^7	10^9	10^{11}	10^{10}	$>10^{12}$
A 1	Sandy loam	8.5	10^3	10^9	10^9	10^{11}	10^5	10^6	10^3	10^5	10^6	10^7	10^7
C 1	Do	7·7	10^3	$>10^{12}$	$>10^{12}$	$>10^{12}$	$>10^{12}$	10^{12}	10^8	10^5	10^6	10^{11}	$>10^{12}$
A 7	Loam	8·2	10^4	$>10^{12}$	$>10^{12}$	10^9	10^{11}	10^7	10^5	10^6	10^8	$>10^{12}$	10^{12}
A 20	Do	6·6	10^2	10^{10}	10^{11}	10^{11}	10^8	10^8	10^6	10^6	10^5	10^8	10^9
B 3	Do	8·2	10^3	10^8	10^8	10^6	10^9	10^{11}	10^3	10^4	10^4	10^8	$>10^{12}$
B 7	Do	8·0	10^5	10^{10}	10^9	10^5	10^7	10^6	10^8	10^6	10^8	10^7	10^{10}
B 15	Do	6·0	10^4	10^{10}	10^{11}	10^{12}	10^7	$>10^{12}$	$>10^{12}$	10^5	10^{11}	10^{11}	10^{12}
C 10	Do	6·6	10^5	$>10^{12}$	10^4	10^{11}	10^9	$>10^{12}$	10^5	10^{10}	10^5	10^6	$>10^{12}$
C 14	Do	6·2	10^3	$>10^{12}$	$>10^{12}$	$>10^{12}$	$>10^{12}$	$>10^{12}$	$>10^{12}$	$>10^{12}$	10^6	$>10^{12}$	$>10^{12}$
C 16	Do	8·1	10^4	10^{10}	$>10^{12}$	$>10^{12}$	$>10^{12}$	$>10^{12}$	10^{10}	10^6	10^{11}	$>10^{12}$	$>10^{12}$
A 10	Silty loam	5·5	10^3	10^5	10^{12}	10^{10}	10^6	10^3	10^4	10^5	10^6	10^5	10^8

TABLE V. (*Contd.*)

Soil No.	Soil type	Soil pH	Cellulose	Starch	Pectin	Glucose	Fructose	Glycerol	Sodium citrate	Sodium oleate	Sodium urate	Sodium hippurate	Asparagine
C 24	Do	8·4	104	10^{12}	$>10^{12}$	10^{12}	10^{10}	10^{10}	10^{10}	10^{11}	106	109	108
A 11	Clayey loam	5·2	103	$>10^{12}$	10^{11}	106	105	104	105	104	104	104	$>10^{12}$
A 12	Do	3·0	103	103	106	104	104	103	<103	<103	103	<103	103
A 15	Do	8·1	104	106	10^{11}	107	105	105	103	104	105	106	10^{11}
A 21	Do	8·4	105	$>10^{12}$	108	$>10^{12}$	$>10^{12}$	$>10^{12}$	$>10^{12}$	105	$>10^{12}$	107	$>10^{12}$
B 9	Do	7·7	103	106	106	105	105	104	105	104	105	104	105
B 10	Do	7·5	107	$>10^{12}$	$>10^{12}$	10^{10}	107	10^{10}	106	104	10^{12}	10^{10}	$>10^{12}$
B 12	Do	5·9	105	10^{10}	10^{10}	$>10^{12}$	107	10^{10}	108	106	108	108	108
B 25	Do	6·6	103	10^{12}	10^{11}	$>10^{12}$	$>10^{12}$	$>10^{12}$	108	106	$>10^{12}$	$>10^{12}$	$>10^{12}$
C 12	Do	7·8	<103	$>10^{12}$	105	$>10^{12}$	109	$>10^{12}$	108	10^{10}	109	10^{12}	$>10^{12}$
C 17	Do	7·4	10^{10}	$>10^{12}$	$>10^{12}$	$>10^{12}$	$>10^{12}$	$>10^{12}$	$>10^{12}$	$>10^{12}$	$>10^{12}$	$>10^{12}$	$>10^{12}$
A 6	Clay	8·1	<103	10^{11}	$>10^{12}$	107	108	108	106	106	108	109	107
B 5	Do	5·6	106	$>10^{12}$	$>10^{12}$	10^{11}	10^{10}	$>10^{12}$	108	106	107	10^{12}	$>10^{12}$
C 9	Do	8·8	104	10^{12}	10^{10}	108	108	107	108	$>10^{12}$	$>10^{12}$	$>10^{12}$	$>10^{12}$
C 18	Do	7·9	104	$>10^{12}$	$>10^{12}$	$>10^{12}$	$>10^{12}$	106	106	108	106	10^{11}	$>10^{12}$
C 21	Do	8·7	105	10^{10}	$>10^{12}$	109	10^{11}	$>10^{12}$	10^{10}	105	105	10^{10}	$>10^{12}$

Pseudomonas was the commonest and the most versatile microorganism to be encountered in most soils. All the 16 substrates employed in the study (cellulose, starch, pectin, glucose, fructose, glycerol, citrate, oleate, urate, hippurate, asparagine, benzoate, glutamate, glycine, inositol and sucrose) were able to enrich *Pseudomonas*.

The decomposition of glutamate, benzoate, oleate, inositol and citrate in soils was mainly due to Pseudomonads.

The sporeforming bacilli appear to be more important than the Pseudomonads in urate decomposition in soil. The same was true of sporeforming bacilli in the decomposition of pectin in the coarser sandy and sandy loam soils.

The enrichment of Coryneform bactera of soil by asparagine, glycerol, starch, glucose, hippurate and especially by glycine suggests their role in the transformation of these substrates in soil.

Sucrose was the only substrate which could persistently enrich microorganisms of the *Enterobacteriaceae* family—*Aerobacter* and *Paracolobactrum*.

The different physiological groups of microorganisms of some select samples of soil have been enumerated by the " extinction dilution " method.

ACKNOWLEDGEMENTS

The authors wish to acknowledge the technical assistance received from Mr. A. Gonsalves. They are indebted to Drs. M. S. Thacker, S. Bhagavantam and B. N. Uppal for their keen interest in these studies and to the Indian Council of Agricultural Research for financing the scheme on the results of which this paper is based.

REFERENCES

Betrabet, S. M. and Bhat, J. V. 1958. Pectin decomposition by species of *Pseudomonas* and their role in the retting of malvaceous plants. *Appl. Microbiol.* **6**: 89.

Breed, R. S., Murray, E. G. D. and Hitchens, A. P. 1948. *Bergey's Manual of Determinative Bacteriology*. 6th edn. The Williams & Wilkins Co., Baltimore, Md.

Khambata, S. R. and Bhat, J. V. 1955. Flagellated coryneform bacteria from the intestine of earthworms. *Arch. für Mikrobiol.* **22**: 175-79.

Potter, L. F. and McCoy, E. F. 1952. The fermentation of pectin and pectic acid by *Clostridium felsineum*. *J. Bact.* **64**: 701-08.

Skinner, C. E., Emmons, C. W. and Tsuchiya, H. M. 1947. *Henrici's Molds, Yeasts*, and *Actinomycetes*. 2nd edn. John Wiley & Sons, Inc., New York.

Smith, G. 1946. *An Introduction to Industrial Mycology*. 3rd edn. Edward Arnold & Co. Ltd., London.

Society of American Bacteriologists 1946. *Manual of Methods for Pure culture Study of Bacteria*. Biotechnical Publications, Geneva, N.Y.

EFFECT OF EARTHWORMS ON THE MICROFLORA OF SOIL

J. V. BHAT, S. R. KHAMBATA[1], MAYA G. BHAT, C. A. SASTRY[2], RAJUL V. IYER and V. IYER[3]

Indian Institute of Science, Bangalore 12

Received : November 4, 1959.

The influence of earthworms on soil structure and plant productivity of the soil has been a subject of extensive investigations in the past but their influence on the microflora of soils has received relatively scant attention. Bassalik (1913) noted no difference between the types of bacteria encountered in the alimentary tract of *Lumbricus terrestris* and those found in the soil from which the earthworms were collected. The burrows of earthworms lined with their castings were found to be rich in bacteria by Düggeli (1927). A similar observation on the increased bacterial content of casts in comparison with undisturbed soil was made by Stöckli (1928) and he also reported the favourable influence of earthworms on the number of physiological groups of soil bacteria. Lindquist (1941) found that worms contributed to nitrification in soil by stimulating bacterial activity. According to Kelkar (1949) the number of bacteria was generally less in casts though the nitrifying power of the casts was higher than the corresponding soils. Day (1950) noticed no consistent increase or decrease in the total population of bacteria, Actinomycetes and fungi in fresh casts of *L. terrestris* as compared to the soil. However, he found that while passing through the alimentary canal of earthworm the number of nitrifying bacteria did not markedly increase or decrease whereas *Bacillus cereus* var. *mycoides* underwent slight reduction in number and *Serratia marcescens* was completely killed. Literature pertaining to the role of earthworms in agriculture has recently appeared elsewhere (Bhat and Khambata, 1959).

In most of the studies referred to above, a comparison is made of the micro-organisms in the soil which is ingested by the worm and of the microorganisms in the fresh castings formed from this soil. The present paper, however, deals with field and laboratory experiments conducted to study the microflora of soils in containers with and without earthworms. Information on the influence of earthworms on the total bacterial, actinomycal and fungal populations as well as on the types and numbers of specific physiological groups of soil microorganisms was sought, and the results of these experiments are reported in this paper.

MATERIAL AND METHODS

Maintenance of earthworms: Adult earthworms, collected from the mulberry garden of the Indian Institute of Science, were maintained in a large wooden culture box containing soil mixed with hay and dry leaves. The latter two were added periodically and the contents of the box maintained moist by daily sprinkling of water.

Present address : 1. Tata-Fison, Bombay.
2. Regional Research Laboratory, Hyderabad.
3. S. B. Garda College, Navasari.

Preparation of boxes for laboratory experiments: Wooden boxes measuring 12 in. × 12 in. × 8 in. were constructed with deal wood planks cut to a width of 1·5 in. and spaced so as to provide air gaps throughout the mass of the soil (Fig. 1). On

Fig. 1. Box for laboratory experiment

one side the plank at the base of each box was removable and facilitated the withdrawal of soil and earthworms from the bottom of the box. In all experiments the red loam soil from the mulberry garden after sieving through a 0·25 in. screen was used. The soil, free from clumps and earthworms, in Experiment I, was thoroughly mixed with animal and vegetable manure (8:2:2). The animal manure was from a compost heap and consisted mainly of dung whereas the vegetable manure was made up of vegetable waste, weeds, grasses and decaying leaves. The boxes were filled upto a height of 4·5 in. and maintained moist by frequently sprinkling water on them.

Preparation of iron cylinders for field experiments: Galvanized iron cylinders (15 in. tall and 11 in. diameter) open at both ends were constructed. The bottom of each of these was fitted with a fine wire mesh. Three pits in a row, 3 ft. apart, were dug into the soil of the mulberry garden such that the tall mulberry plants growing in parallel rows afforded protection from the inclemencies of weather (Fig. 2). The cylinders with their wire mesh bottoms were lowered one in each pit so that they protruded only a few inches above ground level (Fig. 3). The soil from the dug pits was rendered clump-free by sieving, mixed with a good amount of chopped hay, and packed well into the cylinders. The wire meshing at the bottom of the cylinders prevented the movement of earthworms from and to the cylinders and permitted, at the same time, effective contact between the cylinder soil and subsoil. A removable protective wire mesh lid was fixed on top of each cylinder. The experiments were started after 15 days of setting up the cylinder so as to allow the hay to decompose.

FIG 2. GALVANIZED IRON CYLINDER USED IN EXPERIMENTS.

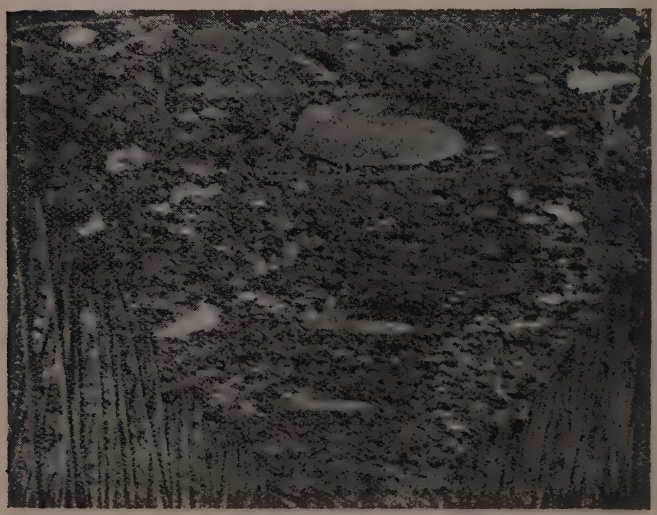


FIG. 3. PLACEMENT OF CYLINDERS IN PITS.

No organic matter was subsequently added and care was taken to see that the cylinder contents remained moist by sprinkling water or allowing rain to fall on them.

Sampling and inoculation with earthworm: At the start of each experiment a composite sample from the wooden boxes or iron cylinders was withdrawn for analysis followed by earthworm inoculation.

In Experiment I, 50 adult worms were inoculated in one box, the other serving as control. Sampling and analysis of soils was done after 1, 3 and 6 months after the start of the experiment. After sampling at 1 and 3 months, some more manure mixture was added to the boxes.

In Experiment II, 0, 50 and 100 adult worms were added to the three cylinders. Sampling was done at monthly intervals for three months.

In Experiment III, a soil-hay mixture (*see* preparation of iron cylinders for field experiments) was filled in four wooden boxes and allowed to decompose for 15 days and maintained moist. The wooden boxes contained 0, 50, 100 and 200 adult earthworms. Sampling was done at weekly intervals for one month as it was found from the previous two experiments that the earthworms died out if the experimental period was longer.

In Experiment IV, the three cylinders were inoculated with 0, 100 and 200 adult earthworms. Sampling was done as in Experiment III above.

Soil analysis: The enrichment culture method was used to determine the various physiologically active groups of microorganisms as also the numbers in which these were present (Khambata *et al.* 1960). The bacteria were identified by the method of classification of Breed *et al.* (1958) and Smith's monograph (1946) was referred to for the identification of moulds.

Fischer's soil extract agar (modified by the addition of 0·1 per cent peptone), McBeth and Scales' agar and Czapek-Dox-Thom agar were used to count the total numbers of bacteria, Actinomycetes and moulds respectively. Sucrose yeast extract Rose-Bengal ox-gall agar was selected for making yeast counts on the basis of earlier experiments (I.C.A.R. Report, 1957). MacConkey's agar was used for counting Coliform bacteria. *Azotobacter* counts were made on a modified Ashby's nitrogen-free agar containing sucrose and mannitol in 0·5 per cent amounts (Collins and Morris, 1952). The ease with which *Azotobacter* counts could be made on this medium can be seen from Fig. 4.

The colour of soils was determined by reference to the "Munsell Soil Color Charts" (1954), and the pH of the soils was determined on a Beckman pH meter. The moisture and nitrogen content of the samples was also estimated (nitrogen was not determined in Experiment I).

At the end of each experiment the number of worms was counted from each of the earthworm-inoculated containers.

RESULTS

The results of the four experiments have been summarized in Tables I to IV. Only those features of the soil that have undergone a significant change as a result of earthworm activity as compared to the earthworm-free controls have been presented.

TABLE I: EXPERIMENT I. pH AND *AZOTOBACTER* COUNT OF SOIL

Soil	Time of soil sampling	pH	*Azotobacter* count per g. air-dry soil
Composite sample of soils from 2 boxes	At start of experiment before earthworm inoculation	6·2	169
A	After 1 month	8·3	211
B		8·3	747
A	After 3 months	8·2	232
B		8·2	912
A	After 6 months	8·5	109
B		8·5	303

A=Control soil without earthworm
B=Soil containing 50 earthworms

TABLE II: EXPERIMENT II. pH, TOTAL AND NITRATE NITROGEN AND *AZOTOBACTER* COUNT OF SOIL

Soil	Time of soil sampling	pH	Total N (per cent)	Nitrate Np.p.m.	*Azotobacter* count per g. air-dry soil
Composite sample of soils from 3 cylinders	At start of experiment before earthworm inoculation	7·2	0·1092	2·2	372
A	After 1 month	7·6	0·0994	2·0	36
B		7·4	0·1008	2·4	294
C		7·5	0·1036	3·3	2·141
A	After 2 months	7·3	0·0886	2·4	189
B		7·3	0·0952	2·7	10
C		7·2	0·0966	4·2	595
A	After 3 months	7·3	0·0824	1·8	110
B		7·4	0·0836	2·9	16
C		7·2	0·0838	3·2	317

A=Control soil without earthworms
B=Soil containing 50 earthworms
C=Soil containing 100 earthworms

Types and numbers of physiological groups of microorganisms

These observations were restricted to Experiments I and II since it was noticed that the types and numbers of microorganisms encountered in the various enrichments did not show any marked difference between the control and experimental

FIG. 4.

soil samples. The substrates used for experiment I were cellulose, pectin, starch, sodium citrate, sodium oleate, glycerol, sodium urate, sodium hippurate and asparagine; those for Experiment II were pectin, sucrose, sodium oleate, i-inositol, glycine asparagine and sodium oxalate.

Total counts of bacteria, actinomycetes and moulds

Total counts were made only for Experiments I and II and were abandoned later because the increase or decrease in counts were not consistently observed.

Yeast count: Yeasts were found to be absent from the mulberry garden soil and the counts were discontinued after Experiment I.

Coliform count: MacConkey's agar was not found to be a suitable medium for counting soil coliform bacteria as it also permitted the growth of *Pseudomonas* and *Alcaligenes* group of organisms and rendered a true coliform count impossible. Counts for these organisms were abandoned after Experiment II.

Azotobacter count: The number of *Azotobacter* were found to be consistently higher in the experimental soils in all the four experiments as compared to the controls.

TABLE III: EXPERIMENT III. pH, TOTAL AND NITRATE NITROGEN, AND *AZOTOBACTER* COUNT OF SOIL

Soil	Time of soil sampling	pH	Total N (per cent)	Nitrate Np.p.m.	*Azotobacter* count per g. air-dry soil
Composite sample of soils from 4 boxes	At start of experiment before earthworm inoculation	7·6	0·0882	1·8	263
A	After 1 week	7·7	0·0854	1·4	171
B		7·5	0·0910	1·9	258
C		7·3	0·0924	2·2	273
D		7·2	0·0994	2·6	1,495
A	After 2 weeks	7·5	0·0868	2·0	63
B		7·3	0·0882	2·1	181
C		7·7	0·0882	2·2	338
D		7·4	0·0952	2·7	1,067
A	After 3 weeks	7·6	0·0840	1·9	177
B		7·5	0·0868	2·0	214
C		7·6	0·0875	2·0	318
D		7·5	0·0924	2·8	1,125
A	After 4 weeks	7·4	0·0826	1·2	258
B		7·6	0·0840	1·5	455
C		7·2	0·0840	1·6	206
D		7·1	0·0882	2·2	3,692

A=Control soil without earthworm.
B=Soil containing 50 earthworms.
C=Soil containing 100 earthworms.
D=Soil containing 200 earthworms.

Colour and pH: There was not much change in the colour of the soils as a result of earthworm activity. Although there was no difference in pH of control and experimental soils in Experiment I, in the rest of the experiments it was consistently noticed that the experimental soils tended to be neutral in reaction than the comparatively more alkaline controls.

Moisture: The total and capillary moisture had not undergone any change as a result of earthworm activity.

Nitrogen content: The total nitrogen content of earthworm-bearing soils was throughout observed to be slightly higher than that of control soils indicating thereby that the loss of nitrogen from the experimental soils was prevented. In Experiments II and III it was observed that nitrate nitrogen was appreciably higher in experimental soils,

TABLE IV: EXPERIMENT IV. pH, TOTAL NITROGEN AND *AZOTOBACTER* COUNT OF SOIL

Soil	Time of soil sampling	pH	Total N (per cent)	*Azotobacter* count per g. air-dry soil
Composite samples of soils from 3 cylinders	At start of experiment before earthworm inoculation	7·4	0·1036	12,110
A	After 1 week	7·5	0·1120	1,013
B		7·4	0·1190	3,788
C		7·0	0·1218	4,527
A	After 2 weeks	7·6	0·1120	233
B		7·4	0·1148	15,300
C		7·3	0·1204	8,004
A	After 3 weeks	7·6	0·1078	12,300
B		7·5	0·1134	6,689
C		7·4	0·1204	25,860
A	After 4 weeks	7·7	0·1050	102
B		7·1	0·1106	15,250
C		7·6	0·1124	13,430

A=Control soil without earthworms
B=Soil containing 100 earthworms
C=Soil containing 200 earthworms

specially in those with 100 or 200 earthworms than the earthworm-free soils. It was also noted in Experiment II that nitrification was more apparent in the nitrifying enrichment media inoculated with experimental soils.

Earthworm population at the end of the experiments: In all the experiments it was noted that the number of earthworms recovered at the end of the observation period had decreased. A number of immature earthworms were always found.

DISCUSSION

The results presented above indicate that changes in the numbers of organisms associated with the degradation of certain organic soil substrates and the altered counts of bacteria, actinomycetes, and fungi are not very marked nor can they be said to have resulted due to earthworm activity. This is an observation similar to that made by Day (1950). The increased *Azotobacter* counts in earthworm-containing soils corroborates Stöckli's (1928) observation on the beneficial influence of earthworms on the numbers of nitrogen-fixing bacteria. The significance of this observation and its implications in soil fertility need hardly be stressed.

The increase noted in the nitrate nitrogen content of experimental soils could be due to *Azotobacter* activity. However, it was observed that the soils inoculated with small numbers of earthworms did not always record a higher *Azotobacter* count than the control. In such cases, the accompanying slight increase in nitrate nitrogen could be due to the decay of dead earthworms (Russell, 1910; Lindquist, 1941).

Whether earthworms influence any specific microorganisms, or whether the increased *Azotobacter* counts that result from their presence in soils is due to increased soil aeration that they could possibly bring about, only further experiments along the lines suggested by Day's work could clarify.

SUMMARY

Laboratory as well as field experiments have shown that earthworms and their activity in soil cause an increase in the total *Azotobacter* counts, probably as a result of which the nitrogen and nitrate nitrogen contents of soils are also increased. Earthworms were not found to significantly alter the number of total soil bacteria, actinomycetes or fungi or the types and numbers of organisms bringing about degradation of specific organic soil substrates.

ACKNOWLEDGEMENTS

The authors wish to thank Drs. M. S. Thacker, S. Bhagavantam, B. N. Uppal and S. V. Govinda Rajan for their keen interest in these studies and to the Indian Council of Agricultural Research for financing the Scheme on the results of which this paper is based.

REFERENCES

Bassalik, K. 1913. Über die Verarbeitung der Oxalsäure durch *Bacillus extorquens* n. sp. *Jb. wiss. Bot. Sci.* **53**: 255.

Bhat, J. V. and Khambata, S. R. 1959. *Role of earthworms in Agriculture.* Indian Council of Agricultural Research, New Delhi.

Breed, R. S., Murray, E. G. D. and Hitchens, A. P. 1948. *Bergey's Manual of Determinative Bacteriology.* Sixth Edn. The Williams and Wilkins Co., Baltimore, Md.

Collins, F. M. and Morris, K. 1952. The occurrence of Azotobacter in two South Australian Soils. *Austr. J. Exp. Biol. med. Sci.* **30**: 587.

Day, G. M. 1950. Influence of earthworms on soil microorganisms. *Soil Sci.* **69**: 175.

Düggeli, M. 1927. Ueber das Verdringen der Bakterien in bedeutende Bodentiefen. *Ber. schweiz. bot. Ges.* **36**.

Indian Council of Agricultural Research 1957. Final report on "The survey of the microflora of soils in relation to their structure, and the role of earthworms in the alteration of the microflora of soils".

Kelkar, B. V. 1949. *Study of nitrification and other processes brought about by earthworms in soils and effect of earthworms on fertility of the soils.* M.Sc. thesis, University of Bombay.

Khambata, S. R., Iyer, V., Iyer, Rajul V., Bhat., Maya G. and Bhat, J. V. 1960. Microflora of some Indian soils as studied by enrichment culture methods (*in press*).

Lindquist, B. 1941. Investigations of the importance of some Scandinavian earthworms for the decomposition of broadleaf litter and for the structure of mull. *Svenska Skogsvsfören. Tidskr.* **39**: 179.

Munsell Soil Color Charts 1954. Munsell Color Company, Inc., Baltimore, Md.

Smith, G. 1946. *An introduction to industrial mycology.* Edward Arnold & Co., London.

Russell, E. J. 1910. The effect of earthworms on soil productiveness. *J. agric. Sci.* **2**: 245.

Stockli, A. 1928. Studien über den Einfluss des Regenwurms auf die Beschaffenheit des Bodens. *Landw. Jb. Schweiz.* **42**: 1.

EFFECT OF FERTILIZERS ON THE MINERAL CONTENTS OF PEARL MILLET (*PENNISETUM TYPHOIDEUM* RICH.) STRAW*

H. C. SHAH and B. V. MEHTA

Institute of Agriculture, Anand (Gujarat)

Received : September 22, 1958

Pearl millet (*Pennisetum typhoideum* Rich.) straw is an important cattle fodder of Gujarat, particularly of Kaira District. Out of the total quantity of dry fodder available (about 6,53,000 tons) in Kaira District, Pearl millet straw (about 3,44,000 tons) constitutes more than 50 per cent of the bulk. Pearl millet is grown all over the district in the monsoon and summer seasons.

Patel and Shah (1956, 1958) studied some common cereal straws in Kaira District and observed that Pearl millet straw was superior to paddy (*Oryza sativa*) straw in all respects except ether extract. It was, however, inferior to *jowar* (*Andropogon sorghum*) straw.

The mineral composition of grasses and fodder crops is known to be affected by several factors, such as species, maturity, rainfall and other climatic conditions, difference in soils, use of soil amendments or fertilizers, etc. Patel and Shah (1958), Murphy (1936), Cartmill (1944), and Roy and Sen (1933) observed that among the different factors influencing the mineral composition of different straws, rainfall was an important factor and lower mineral content was associated with heavier rainfall. Cruickshank (1926) and Woodman *et al.* (1926) working with pasture plants also observed such variations in the mineral composition due to season and rainfall.

Very few well-controlled Indian experiments have come to our notice regarding the effect of manuring on the composition of fodder plants. On account of the acute shortage of ammonium sulphate, it was thought worthwhile to try ammonium chloride as a fertilizer which is considered a good alternative at least for cereal crops. The present investigation was, therefore, undertaken to study the variations in the mineral composition of Pearl millet straw grown on sandy loam soil, popularly known as *goradu* soil, by the application of ammonium chloride and other nitrogenous fertilizers with and without added phosphorus. The present study has also afforded an opportunity to study the seasonal variation in the mineral composition of the Pearl millet straw.

MATERIAL AND METHODS

Field experiments carried out at the College Agronomy Farm of the Institute of Agriculture, Anand (B.S.) were continued for a two-year period covering three crop seasons, monsoon 1956, summer 1957, and monsoon 1957. The Pearl millet seed used in the present investigation was an improved strain, Pearl millet—207. The design of the experiment was a completely Randomized Block Design with four replications and twenty-four treatments. The fertilizers used were: ammonium chloride (AC), ammonium sulphate (AS), ammonium sulphate-nitrate (ASN), ammonium nitrate

* Based on Master's thesis submitted to Sardar Vallabhbhai University, Anand, by the senior author.

(AN), urea (U), groundnut cake (GNC), and farmyard manure (FYM). The levels of nitrogen were 0, 20, and 40 lb. per acre. Phosphorus was applied in the form of single superphosphate at the rate of 40 lb. of P_2O_5 per acre. A control was kept with no manure. The gross plot size was 20 ft. × 8 ft. and the net plot size was 16 ft. × 4 ft. The composition of the soil on which the experiment was carried out is presented in Table I and the climatographical data of the years 1956-57 and 1957-58 are presented in Table II. Samples of leaf and stem for chemical analysis were taken at the harvest time. Ten plants were selected at random in each plot and the leaves from these ten plants were plucked, combined, dried, weighed and powdered in a Wiley Mill. The ten stems were then cut at the first node above the ground. They were also dried, weighed, and powdered. All these samples were preserved in glass stoppered bottles to await analysis.

TABLE I. COMPOSITION OF THE SANDY LOAM (GORADU) SOIL PROFILE

(Per cent on air-dry basis)

Constituent	DEPTH					
	0″ – 6″	6″ – 12″	1′ – 2′	2′ – 3′	3′ – 4′	4′ – 5′
Coarse sand	0·42	0·48	0·47	0·35	0·54	0·47
Fine sand	80·07	86·00	81·61	71·01	70·87	71·56
Silt	10·75	9·75	9·50	22·50	20·50	21·50
Clay	5·50	1·00	3·75	2·50	2·25	2·75
Loss on ignition	1·24	0·97	0·97	1·46	1·50	1·48
Moisture	1·22	1·17	1·60	2·07	2·67	2·91
Carbonates	Nil	Nil	Nil	Nil	Nil	Nil
Total soluble salts	0·016	0·011	0·0096	0·098	0·032	0·026
Total nitrogen	0·036		0·030	0·034	0·033	0·029
Total phosphorus (mg./100 g.)	434·00		322·00	294·00	356·00	403·00
Readily available phosphorus (mg./100 g.)	9·66		2·76	7·08	7·92	10·49
Water soluble phosphorus (mg./100g.)	0·276		0·184	0·276	0·092	0·092
Total potassium (mg./100 g.)	275·9	254·7	286·5	327·4	312·4	333·5
Base-exchange capacity (me./100 g.)	9·8	9·2	10·5	16·4	17·0	17·9
pH (Soil : Water : : 1 : 5)	7·8	7·8	7·9	8·0	8·0	8·1

Total nitrogen was determined by the Winkler's (1913) boric acid modification of the Kjeldahl's digestion method and crude protein (N × 6·25) was calculated. Phosphorus was determined by the Kilgore's modification of the Pemberton's molybdenum volumetric method as described by Winton and Winton (1945); calcium and magnesium were determined by EDTA ("Versenate") method as described in

TABLE II. SUMMARY OF THE MONTHLY RAINFALL, NUMBER OF RAINY DAYS AND AVERAGE MONTHLY MAXIMUM AND MINIMUM TEMPERATURE DATA

Month	1956					1957				
	Rainfall		Number of rainy days	Average monthly temperature (°F)		Rainfall		Number of rainy days	Average monthly temperature (°F)	
	Inch	Cents		Max.	Min.	Inch	Cents		Max.	Min.
January	..	..	..	84·2	53·3	..	4	1	82·5	51·6
February	..	..	..	89·7	51·3	..	..	..	86·1	48·8
March	..	..	..	94·4	59·9	..	..	..	93·4	60·2
April	..	..	..	105·0	68·6	..	..	..	102·0	69·4
May	..	..	..	106·1	79·4	..	..	..	105·5	72·3
June	..	99	4	99·4	80·2	4	21	5	100·0	79·6
July	21	90	28	85·7	75·8	11	67	21	90·4	77·7
August	18	74	27	85·9	75·1	4	62	14	90·6	77·0
September	1	44	6	91·4	74·6	..	12	1	92·8	73·2
October	2	46	6	90·0	68·6	..	..	..	98·3	68·3
November	..	..	..	87·9	59·7	..	91	..	89·0	62·0
December	..	..	..	84·3	52·0	..	..	..	87·2	51·9
Total	45	53	71	..	..	21	57	43	..	..

"Diagnosis and Improvement of Saline and Alkaline Soils" (1954); sodium and potassium were determined photometrically with the help of Dr. B. Lange's Flame Photometer, Model No. 4, and chlorine was determined by Sander's (1939) modification of Volhard's ferric alum volumetric method.

RESULTS AND DISCUSSION

Results of analysis are given in Tables III, IV and V. Since the chemical reactivity of the four basic cations, Ca^{++}, Mg^{++}, K^{+}, and Na^{+} within the plant structure is dependent upon their presence in ionically active form, it is apparent that the consideration of these basic cations in terms of equivalents would present a better picture of their reactivity than their percentages by weights. Hence the results of analysis have been given in terms of milliequivalents per 100 g. Of the three non-metallic elements, nitrogen, phosphorus, and chlorine, nitrogen has been presented as crude protein and hence expressed as a percentage, while phosphorus (expressed as P_2O_5) and chlorine have been expressed in milliequivalents per 100 g.

TABLE III. NITROGEN, PHOSPHORUS, CHLORINE, CALCIUM, MAGNESIUM, POTASSIUM, AND SODIUM CONTENTS OF PEARL MILLET LEAF AND STEM (MONSOON 1956)

(On oven-dry basis)

Treatment symbol	LEAF							STEM						
	Crude protein	Phosphorus	Chlorine	Calcium	Magnesium	Potassium	Sodium	Crude protein	Phosphorus	Chlorine	Calcium	Magnesium	Potassium	Sodium
	Per cent		m.e. per 100 g.					Per cent		m.e. per 100 g.				
No manure	10·07	41·12	4·68	38·85	29·42	30·74	7·13	1·68	63·60	5·72	13·45	11·67	51·34	3·52
P_{40}	10·50	40·53	7·92	42·55	27·60	31·41	6·47	1·81	54·43	9·61	13·90	11·42	54·32	3·35
AC_{20} P_0	12·25	60·98	16·63	32·05	37·25	30·41	6·30	2·07	65·17	17·86	12·65	12·42	55·79	3·35
AC_{20} P_{40}	11·88	62·38	17·58	36·15	28·00	30·36	5·62	2·18	68·33	19·49	13·15	11·42	56·09	3·21
AC_{40} P_0	12·49	62·80	18·08	30·65	36·50	29·23	5·57	2·23	61·95	20·08	12·60	12·33	54·92	3·10
AC_{40} P_{40}	12·18	63·31	19·77	35·25	27·25	29·86	5·09	2·46	68·29	22·23	13·10	11·25	55·45	3·06
AS_{20} P_0	11·81	59·04	7·94	32·65	41·60	32·10	6·66	1·84	67·87	9·69	12·90	12·50	57·37	3·43
AS_{20} P_{40}	12·45	55·45	6·64	42·30	21·50	32·35	6·17	1·89	69·52	9·94	13·85	10·17	57·60	3·26
AS_{40} P_0	12·64	54·94	5·75	31·10	31·50	33·01	6·04	1·79	68·04	10·17	12·65	11·92	58·08	3·10
AS_{40} P_{40}	14·59	35·41	5·66	40·55	23·10	33·84	5·52	1·91	57·01	10·34	13·75	10·60	58·59	3·01
ASN_{20} P_0	11·09	52·36	6·51	34·70	25·10	31·10	7·52	2·04	62·12	9·77	13·15	10·75	56·55	3·70
ASN_{20} P_{40}	11·88	11·43	6·48	37·40	31·17	31·79	7·30	2·14	64·07	9·92	13·25	11·83	56·96	3·52
ASN_{40} P_0	12·51	47·80	5·49	32·40	21·17	32·35	6·69	2·28	74·55	10·20	13·05	10·17	57·53	3·43
ASN_{40} P_{40}	12·08	47·58	4·68	40·15	23·83	33·05	6·22	2·39	83·93	10·40	13·60	10·67	58·09	3·26
AN_{20} P_0	11·48	42·72	9·04	37·05	30·42	30·84	8·21	2·22	54·18	11·02	13·25	11·75	56·30	3·87
AN_{20} P_{40}	10·41	44·12	10·25	42·55	23·50	31·89	8·00	2·43	57·18	11·24	13·90	10·67	56·86	3·78
AN_{40} P_0	12·04	45·35	10·96	34·95	20·50	32·22	7·21	2·09	60·31	11·61	13·20	10·00	57·35	3·43
AN_{40} P_{40}	10·74	48·22	8·06	48·00	18·10	26·12	6·78	2·38	61·53	11·86	14·40	10·00	57·99	3·15
U_{20} P_0	11·51	51·65	8·14	40·30	19·10	32·04	6·30	2·09	67·70	9·63	13·60	10·00	57·35	3·06
U_{20} P_{40}	10·69	64·32	7·58	44·75	21·50	32·25	6·17	2·16	68·88	9·86	13·95	10·33	58·60	3·01
U_{40} P_0	11·74	81·52	9·69	49·20	26·33	32·75	5·96	2·93	69·26	10·06	14·55	11·10	58·04	2·88
U_{40} P_{40}	11·03	86·42	7·89	49·65	29·00	31·80	5·30	2·38	71·34	10·23	14·65	11·58	58·35	2·83
GNC_{40} P_0	11·42	45·58	9·11	33·30	34·50	31·66	7·00	1·89	62·80	10·45	12·95	12·10	57·24	3·48
FYM_{40} P_0	10·48	42·09	9·19	30·70	37·42	31·35	6·22	2·06	60·52	10·59	12·60	12·50	57·06	3·26

TABLE IV. NITROGEN, PHOSPHORUS, CHLORINE, CALCIUM, MAGNESIUM, POTASSIUM, AND SODIUM CONTENTS OF PEARL MILLET LEAF AND STEM (SUMMER 1957)

(On oven-dry basis)

Treatment symbol	LEAF							STEM						
	Crude protein	Phosphorus	Chlorine	Calcium	Magnesium	Potassium	Sodium	Crude protein	Phosphorus	Chlorine	Calcium	Magnesium	Potassium	Sodium
	Per cent		m.e. per 100 g.					Per cent		m.e. per 100 g.				
No manure	7·02	37·48	5·81	25·60	26·00	31·12	6·57	1·45	61·36	6·23	13·05	11·76	55·94	3·35
P_{40}	9·45	35·92	8·79	31·05	25·25	31·69	6·09	1·57	58·36	9·38	14·35	11·42	56·25	3·13
AC_{20} P_0	9·54	42·56	17·38	25·60	30·08	34·81	6·04	1·62	63·35	17·41	13·85	12·25	56·76	3·61
AC_{20} P_{40}	9·87	43·02	17·52	30·60	29·50	35·35	7·62	1·62	64·74	18·40	14·05	13·08	57·14	3·65
AC_{40} P_0	10·11	47·37	18·43	31·15	31·83	35·73	7·87	1·78	65·55	19·69	14·75	13·67	57·53	3·43
AC_{40} P_{40}	10·54	49·32	19·36	34·85	30·93	36·12	8·40	1·83	65·93	20·17	15·45	14·00	58·01	3·61
AS_{20} P_0	8·78	38·54	8·99	27·05	29·42	33·56	6·61	1·61	62·16	9·77	13·35	12·25	56·96	3·26
AS_{20} P_{40}	9·29	39·60	9·04	30·65	28·92	33·94	6·78	1·63	63·05	9·95	14·15	11·50	58·04	3·43
AS_{40} P_0	9·66	41·46	9·61	31·35	30·17	34·33	7·35	1·66	63·52	10·40	14·40	13·08	58·34	3·26
AS_{40} P_{40}	11·33	42·13	10·02	32·95	29·25	34·76	7·70	1·73	63·60	10·76	14·95	12·42	58·78	3·52
ASN_{20} P_0	8·65	47·04	8·92	26·65	28·42	33·33	6·69	1·59	58·78	10·28	13·55	12·25	56·60	3·09
ASN_{20} P_{40}	8·74	48·22	9·06	28·95	30·25	33·79	7·00	1·68	61·74	10·62	14·05	11·50	57·14	3·21
ASN_{40} P_0	9·52	49·15	9·32	29·40	31·00	34·20	7·49	1·72	63·14	10·74	14·80	12·33	57·58	3·52
ASN_{40} P_{40}	9·42	51·39	9·55	29·95	31·42	35·83	8·22	1·77	64·28	10·81	15·35	11·76	58·04	3·71
AN_{20} P_0	9·87	36·39	9·01	27·05	26·83	33·43	6·83	1·63	61·83	10·98	13·25	11·42	56·76	2·99
AN_{20} P_{40}	9·92	38·96	9·27	29·60	26·60	33·56	7·04	1·66	62·84	11·19	13·55	11·08	57·06	3·09
AN_{40} P_0	10·08	40·36	9·52	30·60	29·33	33·99	7·53	1·69	64·19	11·29	14·35	11·76	57·37	3·21
AN_{40} P_{40}	9·06	41·03	9·61	33·00	26·75	34·84	8·13	1·77	64·66	11·61	14·95	11·42	57·73	3·40
U_{20} P_0	8·68	39·64	8·80	27·55	28·42	32·97	6·14	1·57	61·74	10·42	13·50	11·83	57·24	3·52
U_{20} P_{40}	8·76	40·44	8·90	29·15	27·58	33·92	6·83	1·63	63·18	10·65	14·05	11·83	57·42	3·61
U_{40} P_0	9·11	42·22	9·07	30·60	30·17	34·99	7·04	1·71	63·52	10·74	14·70	11·58	57·65	3·26
U_{40} P_{40}	9·48	47·37	9·30	31·55	28·92	35·73	7·49	1·81	64·62	10·96	15·05	11·08	57·99	3·43
GNC_{40} P_0	8·83	41·12	8·79	25·60	29·58	33·58	6·83	1·55	63·35	10·90	14·35	13·42	57·32	3·18
FYM_{40} P_0	9·98	39·64	8·65	25·95	29·08	33·43	7·21	1·57	61·57	11·24	13·55	11·08	57·19	3·26

TABLE V. NITROGEN, PHOSPHORUS, CHLORINE, CALCIUM, MAGNESIUM, POTASSIUM, AND SODIUM CONTENTS OF PEARL MILLET LEAF AND STEM (MONSOON 1957)

(On oven-dry basis)

Treatment symbol	LEAF							STEM						
	Crude protein	Phosphorus	Chlorine	Calcium	Magnesium	Potassium	Sodium	Crude protein	Phosphorus	Chlorine	Calcium	Magnesium	Potassium	Sodium
	Per cent		m.e. per 100 g.					Per cent		m.e. per 100 g.				
No manure	8·37	37·74	5·38	39·35	30·08	31·28	7·40	1·58	62·93	6·73	13·05	12·08	52·15	3·48
P_{40}	10·57	37·02	7·52	43·15	28·50	32·20	6·74	1·71	56·71	9·77	14·10	11·00	54·92	3·39
AC_{20} P_o	10·81	42·85	17·09	33·50	38·33	30·36	6·86	2·11	65·17	18·36	12·60	11·83	56·91	3·27
AC_{20} P_{40}	11·02	45·73	18·02	37·15	29·25	30·74	6·30	2·20	66·43	19·66	14·10	13·25	57·12	3·18
AC_{40} P_o	11·30	47·80	18·67	32·10	37·33	29·90	6·04	2·27	67·36	20·33	12·35	11·83	55·48	3·04
AC_{40} P_{40}	11·18	49·61	19·63	36·75	28·50	30·41	5·30	2·37	68·76	21·82	14·35	12·42	56·09	2·95
AS_{20} P_o	10·41	41·63	8·11	34·55	40·75	32·53	6·90	1·76	64·95	9·91	12·60	12·75	58·29	3·48
AS_{20} P_{40}	10·89	41·12	7·21	42·95	22·75	32·84	6·39	1·84	66·86	10·28	13·90	10·42	58·39	3·39
AS_{40} P_o	11·31	42·01	6·87	32·35	32·75	33·23	6·39	1·86	65·17	10·62	12·35	13·25	58·68	3·18
AS_{40} P_{40}	11·66	41·37	6·67	41·90	24·75	35·78	5·82	1·92	67·66	10·76	13·50	10·92	58·88	3·04
ASN_{20} P_o	10·45	42·18	7·10	35·60	27·08	31·49	7·82	1·92	64·28	10·28	12·70	12·25	57·37	3·78
ASN_{20} P_{40}	10·63	43·61	7·10	38·30	33·00	32·28	7·52	1·95	64·95	10·62	13·70	10·42	57·78	3·48
ASN_{40} P_o	10·99	45·94	6·79	33·25	22·58	32·92	7·00	1·95	66·86	10·76	12·45	10·92	58·39	3·35
ASN_{40} P_{40}	10·86	47·80	6·59	41·60	24·42	33·43	6·44	2·02	68·12	10·98	13·50	12·08	58·68	3·18
AN_{20} P_o	10·71	39·01	9·52	38·20	31·42	31·36	8·34	2·08	62·93	10·05	12·70	10·92	57·17	3·78
AN_{20} P_{40}	10·99	41·29	9·26	44·00	24·83	32·36	8·13	2·13	64·36	10·39	13·85	10·08	57·63	3·61
AN_{40} P_o	10·97	41·96	8·93	36·15	19·58	32·84	7·58	2·16	63·26	10·76	12·55	10·08	58·16	3·35
AN_{40} P_{40}	9·52	42·64	8·39	49·60	19·58	33·23	7·04	2·27	64·95	10·98	14·10	10·42	58·68	3·04
U_{20} P_o	10·24	40·70	8·22	41·55	21·00	32·54	6·66	1·95	64·11	9·43	12·70	10·67	58·16	2·99
U_{20} P_{40}	10·29	41·58	7·80	45·85	22·67	32·89	6·66	2·02	64·47	9·66	13·85	11·42	58·39	2·99
U_{40} P_o	10·36	42·13	7·29	49·85	27·83	33·23	6·25	2·14	64·28	9·91	12·60	12·25	58·68	2·81
U_{40} P_{40}	9·83	45·77	6·98	49·85	30·25	32·41	5·61	2·22	64·95	10·05	13·50	12·75	58·88	2·81
GNC_{40} P_o	10·21	42·39	9·26	34·45	35·17	31·97	7·35	1·83	64·28	10·22	12·85	12·75	57·88	3·35
FYM_{40} P_o	10·29	44·25	9·10	32·00	38·08	31·67	6·53	1·95	64·95	10·62	12·45	13·25	57·47	3·18

Crude protein

It can be seen from Tables III, IV and V that the leaf contained about five to six times the amount of crude protein contained in the stem. Taking the average of all the three seasons and all the treatments, it was found that the leaf contained 10·38 per cent crude protein and the stem contained 1·93 per cent. Of the total crude protein in the aerial parts of the Pearl millet plant (Shah, 1958) the leaf contained about 40 per cent and the stem about 7·4 per cent. Latshaw and Miller (1924) observed that in the corn plant, the leaf contained about 25 per cent and the stem about 14 per cent of the total crude protein.

It was observed in all the three seasons that the application of phosphorus alone increased the percentage of crude protein in both leaf and stem. The application of nitrogen both alone and in combination with phosphorus also increased the crude protein percentage over no manure. The increases were, of course, of different degrees, according to the level of nitrogen and the form of fertilizer used. Among the different sources of fertilizer-nitrogen, ammonium chloride did not appear to be inferior so far as the crude protein content was concerned, and the highest or near-highest increase in the crude protein content over control was obtained by ammonium chloride in both leaf and stem while the lowest was obtained with urea. Between the two levels of fertilizer-nitrogen, the higher level, viz. 40 lb. per acre, gave a higher crude protein content than the lower level, viz. 20 lb. per acre.

Comparing the crude protein contents seasonwise, it was found that in monsoons there was always a greater content of crude protein than in summer, for both leaf and stem. Patel and Shah (1958) also observed a similar behaviour in their study on the composition of cereal straws in Kaira District. The probable reason may be that in summer the temperatures were high enough (Table II) to facilitate the volatilization of ammonia from the soil, while in monsoons the temperatures were not so high. Sreenivasan and Subrahmanyan (1934), Subrahmanyan (1937), and Madhok and Fazal Uddin (1946) have reported considerable losses of ammonia from soils treated with organic manures and ammoniacal fertilizers. Subrahmanyan (1937) stated that the loss due to volatilization was greater above a temperature of 25°C. and above a pH value of 7·5, and the more the alkaline soil the more was the loss. Wahhab and Fazal Uddin (1954) also reported that when the pH values were on the alkaline side, loss of nitrogen was very high. The alkalinity of the *goradu* soil (Table I), associated with higher temperatures in summer than in monsoons (Table II) might have reduced the amount of nitrogen in the soil, thereby resulting in lower nitrogen contents in the leaf and the stem tissues of the Pearl millet plant in summer.

Between the two monsoon seasons, that of 1956 contained a higher crude protein content in both leaf and stem than that of 1957. Table II shows that in monsoon 1956 there was heavier rainfall than that in monsoon 1957. Thus the higher crude protein content was associated with higher rainfall. Ramiah (1933) also found that the nitrogen, phosphorus and potash contents increased with rainfall.

Phosphorus

Results of analysis presented in Tables III, IV, and V indicate that the stem contained about 1·5 times as much phosphorus as the leaf. Taking the average of

all the three seasons and all the treatments, it was found that the stem contained 63·56 m.e. phosphorus per 100 g. oven-dry material and the leaf contained 45·73 m.e. Of the total phosphorus in the aerial parts of the Pearl millet plant (Shah, 1958), the stem contained 39·4 per cent and the leaf 28·4 per cent.

It was observed in all the three seasons that the application of phosphorus alone in the form of superphosphate did not result in an increase in the phosphorus content of both the leaf and the stem. The application of phosphorus in combination with nitrogen also resulted in only a slight increase in the phosphorus content of the two tissues over that in the treatment of nitrogen alone. This must be true because the soil (Table I) was capable enough to supply the phosphorus needs of the Pearl millet crop (Shah, 1958). The results of Bal and Athawale (1935) also showed that the effect of superphosphate on the phosphorus content of herbage was only slight because the soil was fairly rich with respect to phosphorus. Beeson (1946) also observed that the absolute change in the phosphorus content of the plant was small, generally much less than ten per cent, even with the heaviest applications of phosphates. Moser (1940) was able to increase the level of phosphorus in Australian winter peas and lespedeza from 0·16 per cent to only slightly over 0·20 per cent by applying superphosphate at the rate of 600 lb. per acre to the Cecil sandy loam in pot-tests, and concluded that large quantities of applied phosphates did not result in any greater increase of the phosphorus content of those forages.

Some investigators (Bledsoe and Sell, 1940; Hobbs, 1953; Snider, 1942) have noted that nitrogen fertilization resulted in an increased phosphorus concentration in forages, while others found either no effect (Brown *et al.* 1930; Hall, 1941; Vandecaveye and Baker, 1944) or a depressive effect (Blaser *et al.* 1943; McCall and Woodford, 1938; Tyson, 1939) on phosphorus concentration. The results of the present investigation, in general, (Tables III, IV and V) indicate that the application to the soil of nitrogenous fertilizers either alone or in combination with phosphorus, increased the phosphorus content of both leaf and stem, even though there were some instances where a decrease was observed. In general, between the organic and synthetic sources of fertilizer-nitrogen, synthetic sources gave a higher percentage of phosphorus in both leaf and stem in all the three seasons than the organic ones.

Among the synthetic fertilizers, the general trend was as follows:

Stem
- Monsoon 1956 AN>U>AC>AS>ASN
- Summer 1957 AC>AN>U>AS>ASN
- Monsoon 1957 AC>AS>ASN>U>AN

Leaf
- Monsoon 1956 U>AC>AS>ASN>AN
- Summer 1957 ASN>AC>U>AS>AN
- Monsoon 1957 AC>ASN>U>AS>AN

It is clear that ammonium chloride is not inferior to ammonium sulphate, but there are indications of its being superior. The higher content of phosphorus in the case of ammonium chloride as compared to that in ammonium sulphate may be attributed to the greater solubilizing effect of chloride ion on the insoluble phosphates in the soil than that of sulphate (Desai, 1956). Gausmann *et al.* (1958) working on potatoes

observed that chloride and sulphate can be contrasted in that the higher uptake of P^{32} was attained with chloride as compared with sulphate.

Further, it was a general observation in all the three seasons that 40 lb. nitrogen per acre level both alone and in combination with phosphorus contained a higher amount of phosphorus in both leaf and stem than the respective treatments of 20 lb. nitrogen.

Comparing the phosphorus content seasonwise (Tables III, IV and V) it was observed that there was a higher amount in monsoon season than in summer season, and that between the two monsoon seasons, that of 1956 contained a higher amount of phosphorus than that of 1957. It can be seen from the tables that the trend in phosphorus content is similar to that in crude protein content. Thus phosphorus content was also related to the rainfall and a higher phosphorus content was associated with higher rainfall (compare Tables III and V with Table II). These results are also in accordance with those reported by Ramiah (1933).

Chlorine

Results presented in Tables III, IV and V show that the stem contained somewhat higher amounts of chlorine than the leaf and when calculated as an average of the three seasons and of all the treatments, the chlorine contained in the leaf was 9·90 m.e. per 100 g. oven-dry material and in stem 11·8 m.e. Of the total chlorine contained in the aerial parts of the Pearl millet plant (Shah, 1958), the leaf contained about 40 per cent and stem about 48·4 per cent.

The application of nitrogen and phosphorus, either alone or in combination with each other, resulted in an increased chlorine content in both leaf and stem tissues in all the three seasons. In general, the application of nitrogen increased the chlorine content to a greater extent than did phosphorus application. The average increase in the chlorine content by phosphorus over no-manure for the three seasons was of the order of 52·7 per cent in leaf and 54·3 per cent in stem, while in the case of nitrogen, the average increase was of the order of 60·0 per cent in leaf and 64·0 per cent in stem. Baslavskaya (1936) observed in solution-cultures that addition of nitrogen to the medium decreased the chlorine intake by potatoes and flax, while Selschotter (1935) could find no influence of nitrate on the chlorine content.

It was observed that between the organic and synthetic sources of fertilizer-nitrogen, synthetic sources gave higher content of chlorine in both leaf and stem than the organic ones. Among the synthetic sources the average trend for the three seasons was as follows:

Leaf	AC > AN > U > AS > ASN
Stem	AC > AN > ASN > AS > U

It is clear that in both the tissues ammonium chloride gave the highest chlorine content and that this component was a little more than twice that in other forms of nitrogen. The ratio of the chlorine content in the ammonium chloride and ammonium sulphate treatments in leaf and stem was 2·4:1 and 2·5:1 respectively. Tables III, IV, and V show that the chlorine content increased three to four fold over control by the use of ammonium chloride as a fertilizer. Similar increase in the chlorine content of plants by the use of fertilizers containing chlorine has been reported by other workers. Pettinger (1932), Popp (1931), Garner *et al.* (1903), and Desai (1957) observed that

the chlorine content of the plant tissues increased progressively as the concentration of the added chlorine increased in the medium. Such an increase in the chlorine content of the fodder plants is desirable as it has been reported by Desai (1956) that most of our fodders and feeds are lacking in chlorine and supplements of sodium chloride have to be given to the cattle. It is of particular interest to note that this high accumulation of chlorine in leaf and stem of the Pearl millet plant in the case of ammonium chloride treatments, has not adversely affected either the yield (Shah, 1958) or the crude protein content (Tables III, IV, and V). Thus the increase in the chlorine content of the Pearl millet straw by the use of ammonium chloride as a fertilizer is not likely to deteriorate the quality of the straw.

Calcium and Magnesium

The results presented in Tables III, IV, and V clearly indicate that calcium and magnesium contents were higher in the leaf tissue than the stem tissue and the former contained about three times the calcium and about 2·5 times the magnesium contained in the latter. Taking the average of the three seasons and all the treatments, it was found that leaf contained 36·65 m.e. of calcium and 28·42 m.e. of magnesium per 100 g. of oven-dry material and stem contained 13·55 m.e. of calcium and 11·50 m.e. of magnesium. Of the total calcium and magnesium in aerial parts of the Pearl millet plant (Shah, 1958) the leaf contained 66·3 per cent calcium and 59·0 per cent magnesium while the stem contained 25·2 per cent calcium and 24·0 per cent magnesium.

Comparing the calcium and magnesium contents seasonwise, it was observed that leaf tissue was richer in calcium in monsoon season but stem was richer in summer, while in the case of magnesium both of them contained higher amounts in summer than in monsoons. Between the two monsoons, greater uptake of calcium was observed in monsoon 1957 than in monsoon 1956, probably because of lower rainfall (21 in.) in monsoon 1957 as compared to higher rainfall (42 in.) in monsoon 1956 (Table II). Patel and Shah (1958), Murphy (1936), Cartmill (1944), and Roy and Sen (1933) also observed a similar relationship between the rainfall and the calcium content. Such a relationship between the rainfall and magnesium content was also observed in the present investigation.

It was observed in all the three seasons that the application of fertilizers, both nitrogenous and phosphatic, either alone or in combination with each other altered to some extent both the calcium and magnesium contents of both leaf and stem tissues. In general, the application of fertilizer-nitrogen in any of the forms used except urea, had a tendency to decrease the calcium content and to increase the magnesium content simultaneously, while the application of fertilizer-phosphorus in the form of superphosphate had a tendency to increase the calcium content and to decrease the magnesium content simultaneously. This striking differential behaviour of calcium and magnesium to fertilization suggested that there was an inverse relationship between the two. According to Hunter (1949) there is an antagonistic behaviour between calcium and magnesium and wherever there is an increase in the calcium content, a decrease in the magnesium content may be expected.

Between the organic and synthetic sources of fertilizer-nitrogen, organics gave a higher magnesium content than the synthetic ones in both leaf and stem tissues, but in the case of calcium content there was no such trend. Among the synthetic sources, the application of urea gave the highest calcium content and the application of ammonium chloride the lowest, while ammonium sulphate remained intermediate. In the case of magnesium content the reverse trend was observed. The application of ammonium chloride gave the highest magnesium content in both leaf and stem, and either urea or ammonium nitrate gave the lowest content of magnesium, while ammonium sulphate remained intermediate. These results are in accordance with those of Hunter (1949) regarding the antagonistic behaviour between calcium and magnesium.

Potassium and Sodium

It can be seen from Tables III, IV and V that potassium content was higher in stem than in leaf, while sodium content was higher in leaf than in stem. On an average of the three seasons, the amount of potassium in leaf was 32·70 m.e. and in stem 57·23 m.e. per 100 g. oven-dry material. The amounts of sodium were 6·22 m.e. and 3·31 m.e. per 100 g. oven-dry material. Of the total amount of potassium and sodium in the aerial parts of the Pearl millet plant (Shah, 1958) about 55 per cent potassium was in stem and about 32 per cent potassium in leaf, while only about 15 per cent sodium was in stem and about 28 per cent sodium was in leaf.

In general, the application of nitrogen alone increased the potassium content of both leaf and stem tissues while there was either no change or a slight increase in the sodium content. Similarly when the application of phosphorus alone had a tendency to increase the potassium content, it tended to decrease the sodium content. These results are in accordance with those of Owen (1931) who noted that if phosphates were omitted from the fertilizer the potassium content was depressed. The application of nitrogen in combination with phosphorus gave an increase in the potassium content of both the leaf and the stem, but such an application did not show any definite trend in the sodium content. Further, there was a progressive increase in the potassium content as the level of fertilizer-nitrogen increased from 0 to 40 lb. per acre, and it was also true when nitrogen was applied in combination with phosphorus, while in the case of sodium content there was no regular trend.

Between the organic and synthetic sources of fertilizer nitrogen, on an average, synthetic sources gave higher potassium content than the organic ones in both the leaf and the stem and in all the three seasons. Such a behaviour is rather peculiar, because though organic manures contained potassium, they were not able to increase the potassium content of the plant tissues. The probable reason for such a behaviour might be that ammonium ion of the synthetic fertilizers released potassium from the exchange-complex of the soil at a quicker rate. Among the synthetic sources, in general, ammonium sulphate gave higher potassium content than ammonium chloride in monsoon seasons but these differences were less pronounced in summer. These results are in line with those of calcium contents. This behaviour may be due to the greater leaching losses of the two major cations, viz., calcium and potassium from the soil with ammonium chloride than with ammonium sulphate, the solubility of KCl and $CaCl_2$ being much greater than those of K_2SO_4 and $CaSO_4$. According to

Gausmann, Cunningham, and Struchtemeyer (1958) the chloride added to the soil may be lost due to leaching to the extent of about 93 per cent as compared to only about 62 per cent for sulphate.

When the average potassium and sodium contents of the leaf and stem tissues were compared seasonwise, it was found that the potassium content was always higher in summer season than in monsoons. The sodium content was, however, higher in monsoons than in summer in the case of leaf, while that of stem remained practically unaffected.

SUMMARY

With a view to study the variation in the mineral contents of Pearl millet (*Pennisetum typhoideum* Rich.) straw as affected by the application of ammonium chloride and other fertilizers, field-experiments were carried out at the Institute of Agriculture, Anand (B.S.) over a two-year period covering three crop seasons. Pearl millet was grown on sandy loam soil popularly known as *goradu* soil, and was fertilized with ammonium chloride, ammonium sulphate, ammonium sulphate-nitrate, ammonium nitrate, urea, groundnut cake and farmyard manure, at the rate of 0, 20 and 40 lb. of nitrogen per acre with and without phosphorus added in the form of superphosphate at the rate of 0 and 40 lb. of P_2O_5 per acre.

Application of nitrogen increased crude protein, phosphorus, chlorine, magnesium and potassium contents of both the leaf and the stem but decreased the calcium content while in the case of sodium there was either no change or a slight increase. Application of phosphorus increased crude protein, chlorine, calcium, and potassium contents of both the leaf and the stem, but decreased the magnesium and sodium contents, but gave no increase in the phosphorus content of the leaf and the stem. 40 lb. nitrogen per acre applied as a fertilizer increased the nitrogen, phosphorus, chlorine, magnesium, and potassium contents to a greater extent than did 20 lb. nitrogen per acre. There was no regular trend in the sodium content while in the calcium content there was a decrease over control due to both the levels of fertilizer-nitrogen.

Generally, ammonium chloride gave higher crude protein, phosphorus, chloride, and magnesium contents than ammonium sulphate but in the case of calcium and potassium contents it was next to ammonium sulphate.

Crude protein and phosphorus, contents of both the leaf and the stem were higher in monsoon than in summer, while chlorine, magnesium, and potassium contents were higher in summer than in monsoon. The leaf was richer in calcium and sodium contents in monsoon than in summer, the stem was richer in calcium content in summer than in monsoon and the sodium content of the stem was practically unaffected by the season.

REFERENCES

Bal, D. V. and Athawale, C. R. 1935. Effect of fertilizing and stage of maturity on yield and mineral composition of pasture grass and their bearing on the mineral requirements of cattle of the Central Provinces. *Nagpur Univ. J.* **1**: 11-27.

Baslavskaya, S. S. 1936. The intake and distribution of chloride ion in plants. *Trans. Sci. Inst. Fert. Insecto-fungicides* (*U.S.S.R.*) **130**: 38-48;—as cited by Miller, E. C. (1938). *Plant Physiology*. McGraw-Hill Book Co., Inc., New York.

Beeson, K. C. 1946. The effect of mineral supply on the mineral concentration and nutritional quality of plants. *Bot. Rev.* **12**: 424-55.

Blaser, R. E., Stokes, W. E., Glasscock, R. S. and Killinger, G. B. 1943. The effect of fertilizers on the growth and grazing value of pasture plants. *Proc. Amer. Soc. Soil Sci.* **8**: 271-75.

Bledsoe, R. P. and Sell, O. E. 1940. Permanent pastures. *Bull. Ga. agric. Exp. Sta.* No. 207.

Brown, B. E., Owen, F. V. and Trobey, E. R. 1930. Sources of nitrogen for potatoes in Aroostoock County. *Bull. Maine agric. Exp. Sta.* No. 354.

Cartmill, W. J. 1944. Effects of season, stage of growth, and soil type on the chemical composition of grasses in Queensland "wet belt". *Qd. J. agric. Sci.* **1**: 1-31.

Cruickshank, E. M. 1925. Investigation on the mineral content of pasture grass and its effects on herbirora. IV. Report on the seasonal variation in the mineral contents of pastures. *J. agric. Sci.* **16**: 89-97.

Desai, R. S. 1957. Salt tolerance studies. A contribution to the study of the effect of saline condition on the growth and chemical composition of some crops. Unpublished master's thesis. Gujerat University.

Desai, S. V. 1956. Use of ammonium chloride as a fertilizer. *J. Indian Soc. Soil Sci.* **4**: 3-10.

Diagnosis and Improvement of saline and Alkaline Soils. 1954. U. S. Salinity Laboratory. *Agric. Handb. U.S. Dep. Agric.* **60**.

Garner, W. W., McMurtrey, J. E., Bowling, J. D. and Moss, E. G. 1930. Role of chlorine in nutrition and growth of the tobacco plant and its effect on the quality of the cured leaf. *J. agric. Res.* **40**: 145-59.

Gausmann, H. W., Cunningham, C. E. and Struchtemeyer, R. A. 1958. Effects of chloride and sulphate on P^{32} uptake by potatoes. *Agron. J.* **50**: 90-91.

Hall, T. D. 1941. Fertilizing natural veld and its effect on sward, chemical composition, carrying capacity, and beef production. *S. Afr. J. Sci.* **37**: 111-29.

Hobbs, J. A. 1953. The effect of spring N fertilization on plant characteristics of winter wheat. *Proc. Amer. Soc. Soil Sci.* **17**: 39-42.

Hunter, A. S. 1949. Yield and composition of alfalfa as affected by variation in the Ca–Mg ratio in the soil. *Soil Sci.* **67**: 53-62.

Latshaw, W. L. and Miller, E. C. 1924. Elemental composition of the corn plants. *J. agric. Res.* **27**: 845-61.

Madhok, M. R. and Fazal Uddin 1946. Losses of nitrite nitrogen from soils on desiccation. *Soil Sci.* **61**: 275-80.

McCall, A. G. and Woodford, E. K. 1938. Effects of a liming element on the absorption of individual elements and on the cation-anion balance on wheat. *Pl. Physiol.* **13**: 695-712.

Moser, F. 1940. Plant composition as an index of soil fertility. *Proc. Amer. Soc. Soil Sci.* **5**: 147-51.

Murphy, H. F. 1936. The composition of some great plains grasses and the influence of rainfall on plant composition. *Proc. Okla. Acad. Sci.* **16**: 37-40; 1937. *Herb. Abst.* **7**: 226.

Owen, O. 1931. The analysis of tomato plant. II. The effect of manurial treatments on the composition of tomato foliage. *J. agric. Sci.* **21**: 442-51.

Patel, B. M. and Shah, B. G. 1956. Studies on Jowar fodder (Andropogan sorghaum). *Indian J. agric. Sci.*, **26**: 205-10.

———— and ———— 1958. Studies on the composition of some cereal straws in Kaira District. *Indian J. agric. Sci.* (Accepted for publication).

Pettinger, N. A. 1932. Effect of fertilizers on the chloride content of the sap of corn plants. *J. agric. Res.* **44**: 919-31.

Popp, M. (1931). Fertilizing moors and high lands. *Ernäftr. Pr.* **27**: 262-65; 1932 *Chem. Abst.* **26**: 3602.

Ramiah, P. V. 1933. Studies in South Indian pastures. I. Seasonal variation in the mineral and nitrogen contents of spear grass (Andropogon contortus). *Indian J. vet. Sci. Anim. Husb.* **3**: 65-84.

Roy, A. C. and Sen, K. C. 1933. The seasonal variation in lime and phosphoric acid in some hill pastures. *Agric. Live- st. India.* **3**: 437-47; 1934 *Chem. Abstr.* **4**: 29.

Sanders, G. P. 1939. Determination of chlorine in milk. *J. Diary Sci.* **22**: 841-47.

Selschotter, M. 1935. Nitrogenous fertilizing of tobacco. IV. *Cong. Internatl. Tech. Chin. Indus. Agr. Bruxdles* **2**: 376-82; 1936 *Chem. Abstr.* **30**: 4969.

Shah, H. C. (1958). Use of ammonium chloride as a fertilizer. A contribution to the study of the effect of ammonium chloride on the growth and chemical composition of Pearl millet. Unpublished master's thesis, Gujerat University.

Snider, H. J. 1942. The chemical composition of farm crops as affected by soil type and treatment. *Trans. Ill. Acad. Sci.* **35**: 36-38.

Sreenivasan, A. and Subrahmanyan, V. 1934. Loss of N from swamp soils. *Curr. Sci.* **2**: 432-33.

Subrahmanyan, V. 1937. Volatilization of ammonia from Indian Soils. *Curr. Sci.* **5**: 587-89.

Tyson, J. 1939. Use of fertilizers and lime on native pastures in Michigan. *Tech. Bull. Mich. agric. Exp. Sta.* No. 167.

Vandecaveye, S. C. and Baker, G. O. 1944. Chemical composition of certain forage crops as affected by fertilizers and soil types. *J. agric. Res.* **68**: 191-200.

WAHHAB, A. and FAZAL UDDIN 1954. Loss of N through interaction of ammonia and nitrite ions. *Soil Sci.* **78**: 119-26.

WINKLER, L. W. 1913. The volumetric determination of ammonia. *B. P Z. angew. Chem.* **26**: 231-32; 1913 *Chem. Abstr.* **7**: 2175.

WINTON, A. L. and WINTON, K. B. 1945. *The analysis of foods.* Chapman & Hall Ltd., London.

WOODMAN, H. E. BLUNT, D. L. and STEWART, J. 1926. Nutritive value of pasture. I. Seasonal variations in productivity, botanical and chemical composition and nutritive value of medium pasturage in a light sandy soil. *J. agric. Sci.* **16**: 205-74.

STUDIES ON GERMINATION OF SPRING (*BORO*) AND SUMMER (*AUS*) PADDY TO DETERMINE DORMANCY AND VIABILITY

B. N. GHOSH

Rice Research Station, Chinsurah, West Bengal

Received: September 9, 1958.

Ghosh (1954) found that both *aus* and *boro* paddy require more than a 12 hour day length to flower. In West Bengal more than seven months have 12 hours day length. Therefore, there is every possibility of growing *aus* and *boro* paddy thrice a year, provided there is no dormant period of the seed and that sufficient water supply is assured. If there is any dormancy, an attempt will have to be made to break it by employing embryo culture techniques. With this end in view studies on dormancy and viability of some promising *aus* and *boro* varieties were made and the results are presented in this paper.

MATERIAL AND METHODS

Four *boro* varieties: Chinsurah boro-1, Assam-I, Kakuria and D.I.-3; and three *aus* varieties: Dhairal, Marichbutti and Bhutmuri; were studied in both *boro* and *kharif* season for determining their dormancy and viability. Seeds of these varieties were germinated on moist blotting paper in petri-dishes at room temperature, five petri-dishes being used for each variety. First counting of germination of the seed collected during *kharif* and *boro* season was recorded 15 days after harvest and then a monthly record was maintained up to one year. After that seeds were kept in paraffin-sealed bottles for annual counting. The data is presented in Tables I and II and the temperature and humidity records are shown in Table III.

RESULTS AND DISCUSSION

It was observed that there is no dormant period in Chinsurah boro-1, as the germination percentage of the seed collected during both *boro* and *kharif* seasons was recorded as more than 95, 15 days after harvest. Saran (1947) has reported that the dormancy in early and medium paddy is less as compared to the late ones, that there is an increase in the germination percentage as the time advances from the date of harvesting till an optimum is reached, which when attained lasts for about eight-nine months, and then a decline in the germination percentage is perceptible. It is interesting to note that in Kakuria no dormant period is noticed in the seed collected during *boro* season, while the seed collected during *kharif* shows slight dormant period as the germination percentage is low (59·2). In Bhutmuri, D.I.-3 and Assam-I the percentage is highest in *kharif* season. In two *aus* varieties, Dhairal and Marichbutti, there is a definite dormant period after harvest in both the seasons and they reach an optimum percentage of germination after two-three months of harvest.

TABLE I. PERCENTAGE GERMINATION

(Seed collected during

Variety	Date of Harvest	15 days	45 days ($1\frac{1}{2}$ months)	75 days ($2\frac{1}{2}$ months)	105 days ($3\frac{1}{2}$ months)	135 days ($4\frac{1}{2}$ Months)
Chinsurah *boro*-I	29–9–54	98·4±·43	96·6±·51	96·6±·74	96·8±·42	97·6±·42
Assam-I	30–9–54	88·8±2·33	96·0±·56	96·7±·43	96·4±·58	97·6±·68
Kakuria	4–11–54	59·2±1·64	91·7±·09	93·5±1·21	91·5±1·03	93·5±1·34
D.I.-3	28–10–54	48·3±3·16	75·8±2·07	88·2±·89	91·6±1·94	92·6±·78
Dhairal	5–10–54	7·6±1·18	46·3±1·24	91·8±1·17	96·1±·42	96·5±·70
Marichbutti	27–9–54	29·4±2·14	63·8±1·48	93·6±1·53	94·7±1·23	96·9±·63
Bhutmuri	4–10–54	45·7±1·56	89·0±1·54	96·0±·86	96·0±·58	94·9±·96

TABLE II. PERCENTAGE GERMINATION

(Seed collected during

Variety	Date of Harvest	15 days	45 days ($1\frac{1}{2}$ months)	75 days ($2\frac{1}{2}$ months)	105 days ($3\frac{1}{2}$ months)	135 days ($4\frac{1}{2}$ months)
Chinsura boro-I	21–4–55	98·4±·35	98·0±·60	98·7±·37	97·8±1·42	99·1±·29
Assam-I	19–4–55	51·9±1·58	98·0±·41	98·3±·35	99·0±·29	99·0±·94
Kakuria	25–4–55	97·1±·27	98·6±·14	98·6±·43	98·7±·48	97·1±·92
D.I.-3	22–4–55	83·0±1·79	97·0±·40	98·4±·37	95·4±1·09	97·7±·73
Dhairal	26–4–55	21·9±2·13	76·5±1·87	94·3±·43	96·4±1·18	95·3±·97
Marichbutti	22–4–55	12·6±1·23	86·0±1·32	91·1±1·34	92·4±1·27	95·9±·62
Bhutmuri	23–4–55	71·6±1·25	92·0±1·13	96·3±1·43	94·2±·57	96·2±·79

AFTER HARVEST (AVERAGE OF FIVE REPLICATIONS)

kharif (wet) Season, 1954-55)

165 days (5½ months)	195 days (6½ months)	225 days (7½ months)	255 days (8½ months)	285 days (9½ months)	315 days (10½ months)	345 days (11½ months)
97·9±·69	98·2±0·50	96·7±·52	95·5±·91	96·8±1·14	96·9±·98	97·5±·72
98·3±·39	97·1±1·11	96·0±·93	96·2±·76	97·4±·85	97·2±·73	95·3±·91
92·5±1·10	77·2±1·40	84·9±2·09	91·5±3·98	97·3±·82	79·7±1·84	60·5±1·97
89·2±1·48	82·4±5·47	86·5±1·24	86·6±1·78	91·9±1·78	90·5±1·03	91·9±1·25
96·0±1·07	97·0±·87	95·4±·73	96·2±·76	96·9±3·15	96·8±·85	96·4±·78
96·3±·74	96·3±·38	96·2±·66	93·8±1·25	96·0±·56	97·2±·63	96·9±1·12
97·0±·27	96·2±·78	94·4±·40	93·6±·39	96·0±1·08	99·4±·39	97·1±1·06

AFTER HARVEST (AVERAGE OF FIVE REPLICATIONS)

boro (dry) season, 1954-55)

165 days (5½ months)	195 days (6½ months)	225 days (7½ months)	255 days (8½ months)	285 days (9½ months)	315 days (10½ months)	345 days (11½ months)
98·7±·84	98·3±·80	98·1±·42	98·9±·26	96·1±·77	99·3±·28	97·8±·74
98·1±·78	97·9±·53	97·6±·48	98·1±·42	98·9±·72	98·4±·76	98·7±·45
96·6±·66	97·6±·81	97·8±·98	98·3±·51	98·5±·83	98·3±·31	98·1±·61
96.4±·56	96·2±·37	97·1±·60	97·2±·43	96·7±·80	96·1±·54	97·2±1·14
94·3±1·29	93·9±1·01	95·0±·74	95·0±·67	95·8±·69	95·4±·70	96·8±·67
94·3±·81	91·6±·64	90·5±1·25	91·6±·59	92·0±1·78	92·6±·86	94·2±·42
95·5±·88	94·5±·67	96·9±·29	96·5±·77	94·8±·88	97·0±·66	95·3±·69

Both *boro* and *aus* varieties maintain their optimum percentage of germination throughout the year without any deterioration; in Kakuria, however, deterioration in the germination of seed collected during *kharif* season is noticed after ten months, but no such deterioration is observed in seed collected during *boro* season. After two years, germination percentage of the seed was again recorded and the data are presented in Table IV. All the varieties retain their viability without any deterioration; in Kakuria, however, the seed is collected during *kharif* season and the percentage of germination drops appreciably from 60·5 in the first year to 14·6 in the second year.

This difference in the percentage of germination of the seed collected during *kharif* and *boro* season might possibly be due to the difference in the moisture content of the grain, and temperature and relative humidity of the atmosphere in both the seasons during development of the grain (Table III). Influence of climatic conditions during ripening of seeds and other factors affecting germination have been discussed in detail by Evenari (1956) and Crocker and Barton (1954). Banerji (1937) has shown that the paddy seeds of two varieties, Jhingisail (*aman*) and Jhanji (*aus*), when kept after treating with or without one per cent and two per cent copper sulphate solution and one per cent, three per cent and five per cent ferrous sulphate solution in a cloth bag in an open box, in earthen pot with lid plastered with mud and a third in a glass jar with lid coated with vaseline to make it airtight, lost their viability irrespective of chemical treatments of the seeds, except the seeds when kept in airtight jars. Hedayetullah and Ghosh (1940) have reported that there was no harmful effect on growth and yield of the plants grown from old seed of *aus* variety, Kataktara, kept suitably in desiccators and bottles for about eight years when compared to the growth and yield of the plants from freshly harvested seed. It has also been found at Sabour that paddy seeds stored under airtight conditions such as empty kerosene oil tins after drying them thoroughly in the sun, kept their full viability even after eight years (Saran, 1947). From the above discussion, the conclusion can be drawn that if rice seeds are kept in airtight containers their viability remains intact for a long period.

SUMMARY

Four *boro* and three *aus* varieties of paddy were studied in both *boro* and *kharif* seasons, with a view to determining their dormancy and viability.

The results indicate that there is a difference in germination after harvest in the seed of the same variety of paddy collected during *kharif* and *boro* seasons. The seed of Kakuria shows no dormancy when collected during *boro* season, while the seed collected during *kharif* shows slight dormant period, the germination percentage being 59·2. Similarly in Bhutmuri and D.I.—3 the percentage of germination after harvest during *boro* season is higher than in *kharif*, the increase being 25·9 and 34·7 per cent respectively. The reverse is the case in Assam—I where greater percentage of germination is noticed in the seed collected during *kharif* season, the increase being 36·8 per cent. There is no dormancy in Chinsurah boro—1 as the seeds of both the seasons germinate more than 95 per cent after harvest, while a definite dormant period is noticed in Dhairal and Marichbutti, as the germination percentage is less than 30 in both the seasons.

TABLE III. TEMPERATURE AND HUMIDITY RECORD AT CHINSURAH, 1954-55

Months		Mean temperature in °C		Relative humidity (per cent) at 14·00 hr.
		Maximum	Minimum	
October	1954	30·5	24·3	65
November	,,	28·3	12·7	45
December	,,	26·4	10·7	45
January	1955	25·6	9·7	39
February	,,	29·3	10·7	31
March	,,	35·5	19·8	27
April	,,	36·8	22·6	34
May	,,	35·3	25·6	49
June	,,	33·8	25·6	68
July	,,	31·3	25·4	78
August	,,	29·1	23·2	80
September	,,	31·8	25·6	74
October	,,	30·6	23·6	72
November	,,	28·3	16·8	53
December	,,	25·8	9·9	40
January	1956	26·8	10·6	38
February	,,	27·4	10·6	39
March	,,	31·7	20·7	39
April	,,	37·4	23·6	28

TABLE IV. GERMINATION PERCENTAGE OF TWO-YEAR-OLD PRESERVED SEEDS
(Average of five replications)

Variety	Kharif season	Boro season
Chinsurah boro-I	99·4±0·38	99·4±0·34
Assam—I	94·6±1·90	96·5±1·72
Kakuria	14·6±2·09	97·0±0·77
D. I.—3	94·2±1·60	93·8±2·19
Dhairal	97·9±0·62	Record not taken due to shortage of seeds
Marichbutti	97·6±1·82	–do–
Bhutmuri	96·5±1·19	93·0±2·73

As regards viability, the varieties maintain their optimum germination throughout the first and second year. However, in the seed of Kakuria, collected during *kharif* season the germination drops after ten months from 60·5 per cent in the first year to 14·6 per cent in the second year, but no such deterioration is observed in the seed collected during *boro* season.

From the result of the above study, it seems that the difference in dormancy and viability of the rice seed collected during *kharif* and *boro* season is possibly due to the difference in moisture content of the grain and temperature and relative humidity of the atmosphere during development of the grain in *kharif* and *boro* season.

ACKNOWLEDGEMENTS

Grateful thanks are due to Dr. H. K. Nandi, Director of Agriculture, West Bengal; and to Shri A. K. Paul, Head of the Economic Botany Section, West Bengal for their keen interest in this work. Thanks are due to the Indian Council of Agricultural Research, New Delhi, for a grant-in-aid.

REFERENCES

BANERJI, K. C. 1937. *Annual Rept. on the work done under the Res. Scheme, Bengal*, 1937-38.

CROCKER, W. and BARTON, L. V. 1954. *Physiology of Seeds*. The Chronica Botanica Co.

EVENARI, M. 1956. *Seed germination, Radiation Biology* **3**: (Ed. Alexander Hollaender). McGraw-Hill Book Co., Inc.

GHOSH, B. N. 1954. *Annu. Prog. Rep. work done under the Scheme for Res. to evolve better varieties of boro paddy in West Bengal.*

HEDAYETULLAH, S. and GHOSH, B. N. 1940. *Annu. Rep. Dept. Agric. Bengal* 1940-41.

SARAN, A. B. 1947. *Paddy in Bihar*. Department of Agriculture, Bihar.

EFFECT OF SOWING TIME ON THE DEVELOPMENT AND YIELD OF MAIZE (*ZEA MAYS*) CROP.

KARTAR SINGH CHELA

Block Development Officer, Jagraon

Received: August 29, 1958.

The time of sowing has been noticed to have considerable effect on the yield of crops like maize. Latta (1888), Latta and Anderson (1897), and Robertson (1930) obtained higher maize yields from early planting. Late sown maize fell off rapidly in bushel weight and grain yield. Williams and Welton (1915) found that extremely early or extremely late sowings gave poor yields of corn as compared with normal sowing dates. The amount of barrenness for the latest planting was 2·7 times greater than the earliest sowing. Results of similar nature were reported by Fore (1945), Kiesselbach *et al.* (1935), McClelland (1940), Mitchell (1949) and Hume *et al.* (1956). Thus, the factor of sowing time is very important in maize cultivation.

MATERIAL AND METHODS

The investigations were carried out at the Agricultural Experimental Station, Jullundur, during the years 1950 and 1951. The soil on which the experiment was conducted is of medium fertility. A basic dose of 5 tons of compost per acre with 0·306 per cent nitrogen was applied to the field before laying out the experiment. Four dates of sowing were tried in randomised blocks with four replications. The net plot size after leaving out border effects was 12 ft. × 90·75 ft. or 1/40th of an acre during 1950, and 12 ft. × 75·62 ft. or 1/48th of an acre during 1951. The maize crop came after wheat. The final plant spacing was 12 in. × 12 in. Ammonium sulphate was applied to the entire maize crop at the rate of 50 lb. nitrogen per acre about three weeks after sowing.

The four sowing dates were spaced at ten-day intervals of July 5th, 15th, 25th and 4th of August.

Two hoeings were given to all the sowings. One irrigation was given during the first year due to heavy rains amounting to 47·08 in. received during the growing period, and five irrigations were given during the second year to all these sowings as the rainfall was only 11·63 in.

Ten plants were selected at random in each plot for recording the development data. The plant height was measured in cm. from the base of the plant at ground level up to the base of the tassel about a week before harvesting. The girth of the stalk was measured in cm. at the thickest internode with the help of Vernier Caliper at the final stage of growth. The percentage of borer attacked plants and of barren plants was worked out by counting the total number of healthy and normal plants per net plot and the plants attacked by borer and the plants with no ears developed on them just before harvesting. The shelling percentage was calculated after weighing the ears as a whole after drying and just before threshing and then weighing the cleaned

grains after threshing. The stalk yield was determined after deducting the weight of ears from the total weight of the produce at the time of separating the ears from the stalks.

RESULTS

The experimental results achieved are given in Tables I-III.

TABLE I. AVERAGE HEIGHT AND GIRTH OF PLANTS

Sowing date	Average height (cm.)		Average thickness (cm.)	
	1950	1951	1950	1951
D_1. (5th July)	131·25	132·14	1·05	1·27
D_2. (15th July)	131·70	143·70	1·24	1·28
D_3. (25th July)	128·78	142·17	1·22	1·29
D_4. (4th August)	96·14	128·84	0·93	1·14
S.E. ±	3·23	4·52	0·09	0·04
C.D. at 5 per cent level.	7·31	10·22	0·19	0·09

TABLE II. AVERAGE PERCENTAGE OF BORER ATTACKED, BARREN PLANTS AND SHELLING PERCENTAGE

Sowing date	Borer attacked plants		Barren plants		Shelling percentage	
	1950	1951	1950	1951	1950	1951
D_1.	10·92	23·98	0·60	1·25	79·35	80·22
D_2.	4·85	21·08	4·35	5·35	80·85	81·00
D_3.	5·55	17·82	5·72	6·35	78·05	77·45
D_4.	6·55	13·42	8·55	7·82	59·48	74·00
S.E. ±	1·53	1·37	0·99	0·64	2·84	0·99
C.D.	3·46	3·10	2·24	1·45	6·42	2·24

TABLE III. AVERAGE YIELD PER ACRE (MD.)

Sowing date	Grain		Stalk	
	1950	1951	1950	1951
D_1.	11·20	15·38	26·63	25·95
D_2.	12·31	18·58	39·00	35·40
D_3.	8·94	11·79	30·97	35·10
D_4.	1·35	9·45	18·15	14·63
S.E. (md. per acre) ±	0·97	1·42	3·54	2·49
C.D. at 5 per cent level	2·19	3·21	8·14	5·63

The results show that the crop sown on July 15, produced the tallest plants. The plants were the smallest in the last sowing. There was little variation in the height of plants under D_2 and D_3 sowings in both the years. The difference in height between D_2 and D_1 sowings was not significant in the first year, but was significant

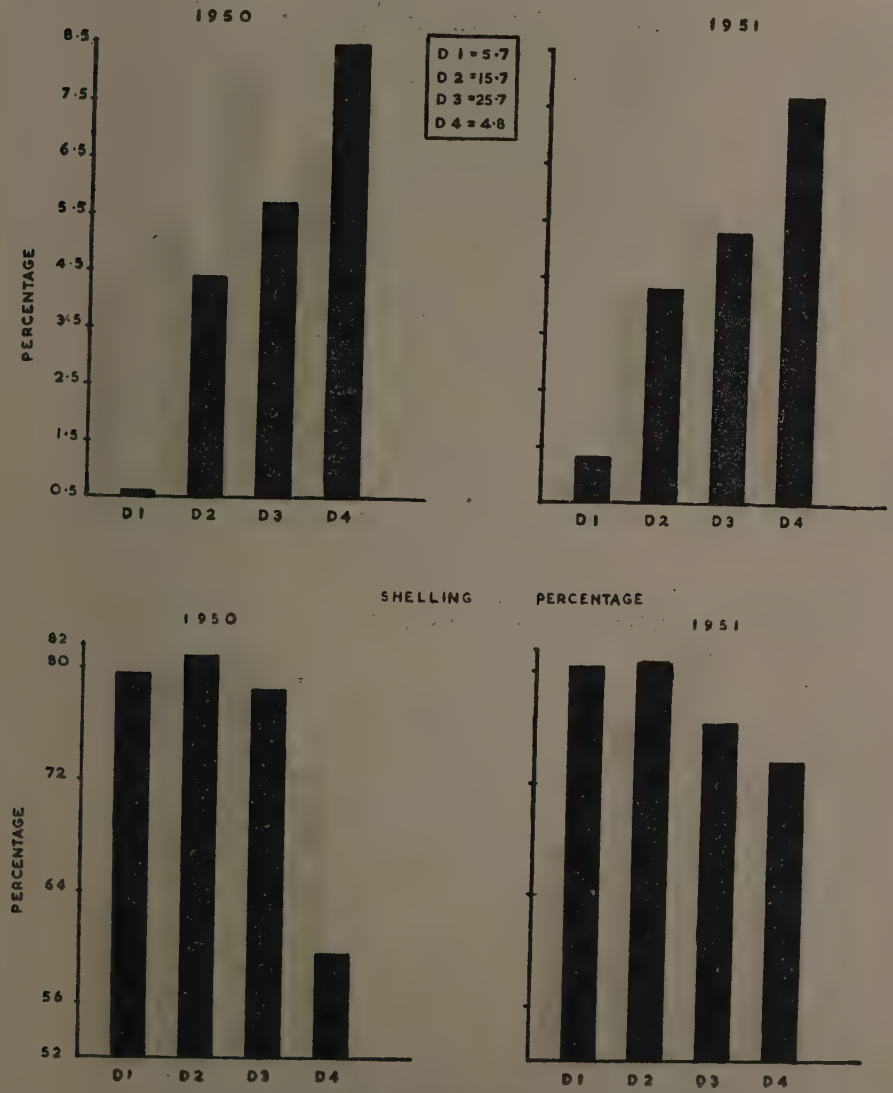


FIG. 1. PERCENTAGE OF BARREN PLANTS.

in the second year. The poor growth of plants in the last sowing is mainly due to the curtailment of the growing period of the crop.

The second and the third sowings gave thicker stems than the first and the fourth sowings. The difference in the thickness of stem between D_2, D_3 and D_1 sowings

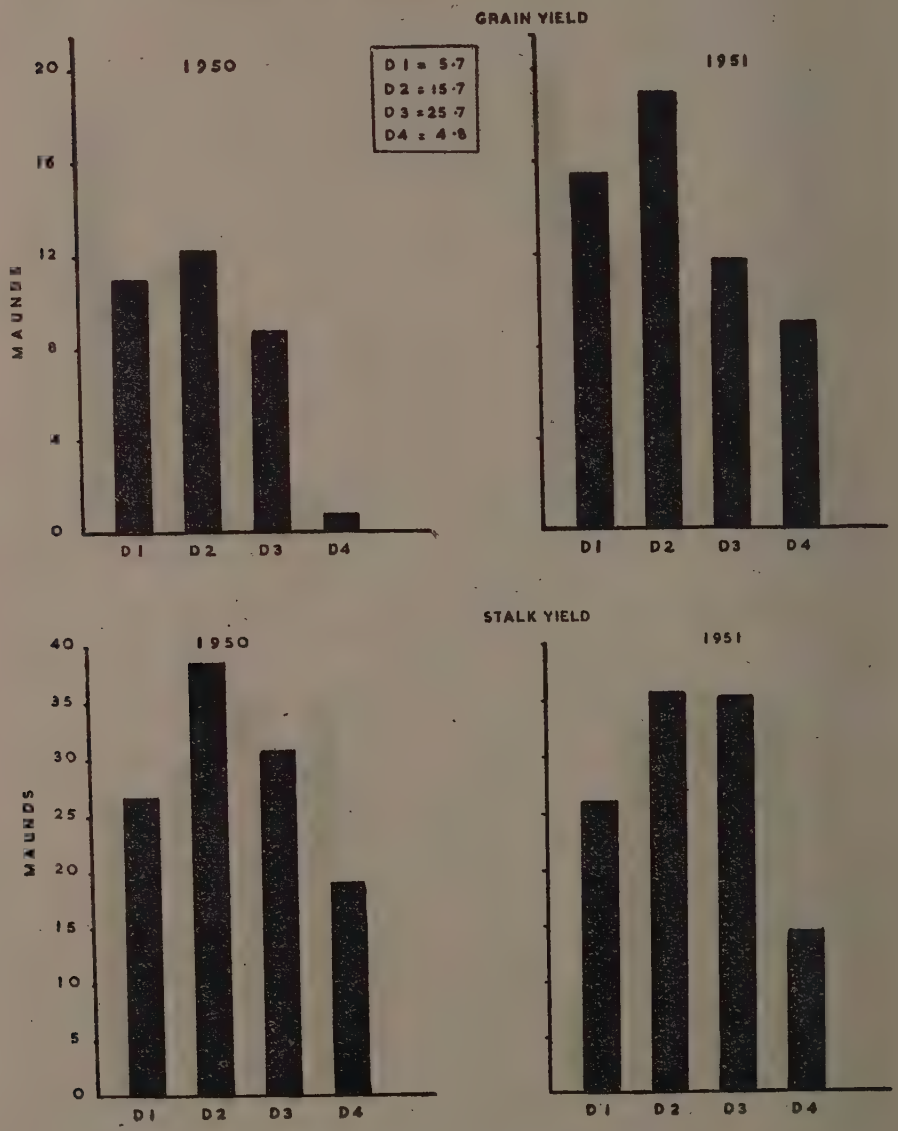


FIG. 2. AVERAGE YIELD PER ACRE IN MAUNDS.

were, however, negligible, but all these three sowings produced significantly thicker stalks than the last sowing.

The percentage of borer (*Chilo zonellus*) attack was highest in the early sown crop in both the years. The three later sowings, which were almost similarly affected by the pest, had significantly lesser attack than the first sowing during the first year. During the second year, the first and the second sowings had a definitely higher percentage of borer infestation than the third and the fourth sowings. The last sowing had the lowest borer attack during this year. Heavy rainfall in the year 1950-51 was very likely to be responsible for the destruction of egg masses and dislodging of young larvae, thereby reducing their effective population for crop infestation. The percentage of borer attack, therefore, was comparatively low in that year.

The percentage of barren plants went on increasing with the advance in the sowing time. The last sowing i.e., the sowing done on the 4th August, had a significantly higher percentage of barren plants than the earlier sowings in both the years (Fig. 1).

The shelling percentage was the highest in second sowing followed by the first, the third and fourth sowings. The development of grains was, therefore, the best in the second sowing followed by the first and third; it was the poorest in the last sowing (Fig. 1). Grain filling is the last phase in cob development and naturally under the last sowing date this character suffered heavily on account of the curtailment of the maturation period and lowering of temperature on the approach of winter.

The crop sown on the 15th July, gave the highest grain outturn per acre in both the years. It was followed by the first sowing by an insignificant margin. Both the second and the first sowings produced a definitely higher yield of grain per acre than the third and the fourth sowings. The difference in the last two sowings was well marked in the first year, but not so in the second year (Fig. 2).

The serial analysis of the grain yield was done to determine the influence of weather on the variation of the crop. The results are indicated in Table IV.

TABLE IV. AVERAGE YIELD PER ACRE (MD.)

Years	Dates				Mean
	D_1	D_2	D_3	D_4	
1950	11·20	12·31	8·94	1·35	= 8·45
1951	15·38	18·58	11·79	9·45	= 13·80
Mean	13·29	15·44	10·36	5·40	
	Dates	*Years*	$D \times Y$		
S.E. m. (Mds. per acre)	± 1·04	± 0·72	± 1·44		
C.D.	2·16	1·50	3·00		

The results indicate that the overall yield of grain was significantly higher in 1951 than in 1950. The D_2 gave the highest yield and proved superior to D_3 and D_4

sowings by a significant margin, but was at par with D_1. The lowest yield of 5·40 md. per acre was recorded in the last sowing. The difference in yield between the last sowing and the other sowings was significant.

The interaction value between the sowing dates and years was not significant indicating that the order of yield for the different sowing dates was the same in the two years of study and the seasonal effect was shared by all sowing dates alike.

As regards the yield of stalks, the second sowing outyielded all other sowings. The second sowing was followed by the third, the first and the fourth sowings. The yield of stalks was the lowest in the fourth sowing (Fig. 2).

DISCUSSION

It was found that amongst the four dates of sowings, tried at ten-day intervals, the second sowing, done on July 15, produced tallest plants, followed closely by July 5 and July 25 sowings. The crop sown on 4th August, was the smallest owing to the shorter period of growth. The attack of borer (*Chilo zonellus*) in the first year, was found to be the greatest in the first sowing and decreased in later sowings. During the second year also, a similar trend of borer attack with varying sowing dates was observed, but the differences between the first and the second sowings were statistically insignificant. The cause of greater damage by borer to the early sown crop appears to be the synchronisation of the best breeding season of this insect pest with the appearance of the seedlings of early sowing.

The percentage of barren plants was decidedly lower in the first sowing than in the remaining three sowings during both the years. The number of barren plants increased with the development of the sowing time and the last sowing had significantly more barren plants than the other sowings. This may be associated with the limitations imposed on the period of growth of this quick growing, short seasoned crop. This is in accord with the results obtained by Williams and Welton (1915).

The development of grain was noticed to be better in the second and the first sowings in both the years. The fourth sowing showed the poorest development of grain as was indicated by the lowest shelling percentage in this case. Improper development of grains under the last sowing is due to the lack of sufficient carbohydrate reserves which could be mobilized for ear development.

The yields of grain and stalk per acre were found to be the highest in the second sowing i.e. the crop sown on the 15th July. The first and the third sowings occupied intermediate positions in this respect. The yields were poorest in the fourth sowing done on 4th August. This is in accord with the findings of Latta (1888), Latta and Anderson (1897) and Robertson *et al.* (1930), and Hume *et al.* (1956).

The serial analysis of grain yield indicated that the order of yield for the different sowing dates was the same in both the years and the seasonal effect was shared by all sowing dates alike.

SUMMARY

Sowing done at ten-day intervals revealed the middle of July to be the optimum sowing time for maize. Earlier and later sowings were attended by reduction in th

yields of grain and stalk. On the whole, the borer attack was the highest in the early sowing (5th July) and least in the last sowing (4th August). The relationship between barrenness and sowing dates was just the reverse—the number of barren stalks being the least in the first sowing and progressively more in the later sowings.

REFERENCES

Fore, R. E. 1945. Field Corn production. *Bull. Ore. agric. Exp. Sta.* No. **434**: 1-41.

Kiesselbach, T. A., Anderson, A. and Lyness, W. E. 1935. Cultural practices in corn production. *Bull. Neb. agric. exp. Sta.* No. **293**: 11-13.

Latta, W. C. 1888. Experiments with oats and corn. *Bull. Ind. agric. Exp. Sta.* No. **14**: 6-20.

———— and Anderson, W. B. 1897. Field experiments with oats and forage crops. *Bull. Purdue Univ. agric. Exp. Sta.* No. **64**: 1-16.

McClelland, C. K. 1940. Varietal and cultural experiments with corn. *Bull. Arkans. agric. Exp. Sta.* No. **402**: 1-30.

Mitchell, W. K. 1949. Growing corn on Red Dirt Soils. *Jamaica Dep. Agric. Ext. Circa.* No. **33**: 1-7.

Robertson, D. W., Kazer, A. and Deming, G. W. 1930. The date to plant corn in Colorado. *Bull. Colo. agric. Exp. Sta.* No. **369**: 1-8.

Williams, C. G. and Welton, F. A. 1915. Corn experiments. *Bull. Ohio agric. Exp. Sta.* No. **282**: 71-109.

Hume, A. N., Drinks, V. A. and Shank, D. B. 1956. Date and rate of corn planting. *Bull. S. Dak. Sta. Coll. agric. Exp. Sta.* No. **455**: 1-34.

REVIEWS

ZYGNEMACEAE. Randhawa, M.S., D.Sc., F.N.I., I.C.S., Published by Indian Council of Agricultural Research, New Delhi—1959. Price Rs. 50 sh.

Zygnemaceae, written by the brilliant Administrator-Botanist, Dr. M. S. Randhawa, is a pioneer scientific publication of India. It is the first of the series of Monographs on Algae being published by the Indian Council of Agricultural Research. The author has made extensive study on the Zygnemaceae of Uttar Pradesh, Punjab and the Himalayan tracts and his valuable contributions are contained in this book.

In the 20th century notable contributions on Zygnemaceae have been made by foreign workers such as Czurda (1922-39), Skuja (1924-49), Strom (1920-26), Skvortzow (1925-37), Hodgetts (1918-25), Transeau (1914-51), Borge (1913), Kolkwitz and Krieger (1944), in addition to studies made by numerous other workers. From 1919 onwards, studies on Indian algae were conducted largely by Indian workers, particularly M. O. P. Iyengar, M. S. Randhawa, and R. N. Singh.

In this monograph, the author has described 174 species of the Zygnemaceae, which is more than that described either by Transeau (1951) or Kolkwitz and Krieger (1944) in their monographs. Most of the described species have been recorded from Assam, Bengal, Madras, Mysore, Uttar Pradesh, the Punjab and Bombay States of India.

This book has given shape to the vast amount of research done on Zygnemaceae in India as well as abroad during the last few years and is a valuable contribution to algology; and is ideally suited for the study of taxonomy of this group.

The monograph contains 478 pages of printed matter. It is divided into 19 chapters, a bibliography and an index of the various genera and species. In the introduction the author has given the history of algae with particular reference to the order Zygnemales and the family Zygnemaceae.

The first chapter includes a discussion on the various classifications of the order, Zygnemales. It appropriately indicates the names of Borge and Pascher who established this order in 1913. The author accepts their classification and has also suggested another classification arranging the genera in the sub-families in an evolutionary sequence. The name Zygnemaceae has been maintained as originally suggested by Menighini (1938). The classification by West (1916), Czurda (1932), Smith (1933), Fritsch (1935), Kolkwitz and Krieger (1944), and Transeau (1951) are also given. This is followed by the characters of Zygnemaceae and its sub-families.

The second chapter deals with the evolution and affinities of Zygnemales and includes a discussion on the views of Schussnig (1925) regarding the derivation of Zygnemales from Chlorococcales, and of Smith (1938-54) who suggested the possibility of their derivation from Volvocales. This has been diagramatically represented. A similar view held by Fritsch (1938), with a remark that the conjugation of *Chlamydomonas eugametas* shows semblance to the process of conjugation in Mesotaeniaceae, has been mentioned. The relationships of the genera of Zygnemaceae to Mesotaeniaceae have

been shown graphically. A discussion of author's views is also incorporated.

The occurrence and distribution of Zygnemaceae, with particular reference to India, is discussed in the third chapter. A map, showing their distribution, is also given. An account of climate and rainfall in India is followed by the periodicity in the occurrence of algae and their distribution in the country.

The cytology of Zygnemaceae is discussed in chapter four. The structure of the cell and its components are treated in detail. The chloroplast and its various types, and the pyrenoid are given attention. The nucleus and the nuclear division are also discussed. These accounts are accompanied by lucid and relevant figures.

The vegetative, asexual and sexual methods of reproduction in Zygnemaceae are discussed in the fifth chapter. Vegetative multiplication in *Mougeotia*, *Spirogyra* and *Zygnemopsis* has been described. Asexual reproduction by akinetes, aplanospores and parthenospores are described. In sexual reproduction, conjugation and the factors, such as pH, which influence the process are enumerated. The isogamous and the anisogamous types of lateral conjugation are discussed with diagrams and pertinent references. Conjugation in different genera is also discussed with a note on the intergeneric hybridization.

Chapter six enumerates the different characters used in the identification of different species. At the end of this chapter references are given for the preceding six chapters.

Chapters seven to nineteen are devoted to a taxonomic account of different genera of Zygnemaceae. Each generic name is followed by its author's name and the year of discovery. The illustrations are clear and are kept close to the text. This should be of great value to students and research workers. The source of each figure is also mentioned. Maps showing the world distribution of the different genera lend clarity to the descriptions and depict phytogeographic limits of the taxa.

Most of the species are described as new by the author. The discovery of the terrestrial species, *Zygnema terrestre*, is particularly noteworthy, because it provides a connecting link between the genera *Zygnema* and *Zygogonium* (*c.f.* p. 15). Further, this alga shows scalariform conjugation in the plains at alt. 1500-1800 m., and exclusively lateral conjugation at 2100-2400 m.; at higher altitudes only akinetes are formed. The largest number of species are described under *Spirogyra* which covers about 147 pages of the text. About 26 species have been recorded in India. *Sirocladium* is a new genus discovered by the author; in this, he describes three species.

The book furnishes proof of the deep love, the author has for algology and his indefatigable energy in writing a book of this magnitude, particularly in view of the fact that he is primarily an administrator.

This book should prove valuable as a text book on algae, particularly at the post graduate level. It should also be very useful in libraries, Research Institutions, Departments of Agriculture, and Public Health Institutions.

The production values are good; the book is printed on art paper in Crown Quarto and has clear and neat diagrams.—J.V.S.

CYANOPHYTA, by T. V. DESIKACHARY, Indian Council of Agricultural Research, New Delhi. Royal 8 vo., pp. 686; October 1959; Price Rs. 37.

The CYANOPHYTA, or blue-green algae, have a bearing on agriculture. Some of them like *Tolypothrix tenuis*, *Calothrix brevissima*, *Anabaena* sp. and *Anabaenopsis* sp. are powerful nitrogen fixers. Paddy fields inoculated with *T. tenuis* have shown increased yields of 15-20 per cent. Evidently these soil algae are of importance to crop production as they favourably affect the soil fertility. These observations are highly significant to Indian conditions where the soils are notoriously poor in nitrogen. A good deal of research work has been done in India on the Indian blue-green algal flora but this lies scattered in numerous journals and this monograph brings under one cover all this large mass of information in a handy and easily accessible form.

CYANOPHYTA is the second in the series of monographs on algae, being published by Indian Council of Agricultural Research. The author, Dr. T. V. Desikachary, is an algologist of distinction and has been working on blue-green algae for over two decades.

The book has been divided into two parts. Part I, covering 69 pages, is devoted to a general account of the CYANOPHYTA and Part II, which extends over 550 pages, concerns with a systematic account of Indian blue-green algae. The general Part opens with a brief statement of the general characters of the CYANOPHYTA and this is followed by a full account of the range of vegetative construction of nonfilamentous and filamentous forms. The structure of the Cyanophycean cell is then dealt with. The processes of photosynthesis and nitrogen fixation in the blue green algae are then touched upon, though one wishes that these were treated in greater detail. It is understood, however, that a monograph on the fixation of nitrogen by CYANOPHYTA, by Dr. R. N. Singh, is shortly to be published by the Indian Council of Agricultural Research, New Delhi. The presence of gas vacuoles in the cells of many species of blue-green algae is a very interesting phenomenon and mention has been made of the several views regarding the nature and function of these vacuoles. A few genera of blue-green algae, such as *Oscillatoria* and others, are well known for the characteristic rapid creeping or gliding movements exhibited by their trichomes and a few unicellular forms show slow movements and a detailed and well-documented account of this aspect of the Cyanophyceae is given. The presence of a mucilaginous envelope or sheath, a universal characteristic of blue-green algae, has received full attention. Then follows a very detailed account of heterocysts extending over seven pages. Branching of the filaments, both true as well as false, is dealt with next and a diagrammatic representation of the different modes of branching is given. Vegetative propagation through hormogones, pseudohormogonia, endospores, resting spores, and other modes is treated next.

The section devoted to various aspects of the biology of blue green algae extends over ten pages and has been treated adequately. An account of marine and salt-water forms follows next and a distinction is sown to exist in that, while a few forms like *Dzensia salina* and *Aphanocapsa littoralis* can be said to be really halophilic, the majority are just halotolerant. A short account is given of species occurring in salt pans and of forms isolated from cultures using crude salt samples from different countries.

Mention is made of a form reported to live in brine at 27 per cent salt content in southern France and forms from California, Siberia and other areas living at 11-27 per cent salt content in lakes. A brief account of the blue-green algal flora of the Indian salt water lakes is also given. Some blue-green algae are known to have calcium incrustation in geologic times and also in the present and a list of such forms is given. Certain species are also known to deposit iron compounds in or on their sheath.

A few species of CYANOPHYTA live in thermal springs and are able to withstand or tolerate rather high temperatures and it is stated that information regarding such algae of India and Ceylon is very meagre. Reference has been made to the Relict hypothesis and Vouk's criticism of the same. Mention has also been made of cold water forms inhabiting Arctic and Antarctic regions.

Symbiotic and other similar associations of several species of blue-green algae with plants and sometimes animals is dealt with next. Sapropelic, colourless and parasitic forms also find a mention.

The section on classification and phylogeny extends over nine pages and contains a review of the various schemes of classification. Classifications of Nägeli, Hansgirg, Thuret, Borzi, and others have been cited. Kirchner is said to be one of the first authors who gave a comprehensive treatment of the entire blue-green algae. Fritsch's classification with some modifications is the one accepted by the present author. *Mastigocladus* and *Brachytrichia* are included under one family, Mastigocladaceae. The genera *Richelia* and *Raphidiopsis* are placed in the Nostocaceae. The views of different authorities regarding evolution within the CYANOPHYTA and schematic diagrams illustrating these views are given.

The most outstanding part of the work is, however, Part II which deals with the systematics of the Indian CYANOPHYTA. The introduction to this part appropriately gives a brief history of the study of Indian blue-green algae. The first species (*Calothrix indica*) was recorded from Assam more than 110 years ago by Montagne and since then, 180 papers have been published on the Indian species, dealing with about 85 genera and 750 species, compared to a world total of 160 genera and 1,500 species. About 170 species, or 22 per cent of the Indian flora, have been reported only from India; while about 145 species, making about 20 per cent, are cosmopolitan. A good percentage of the Indian blue-greens are represented in the Russian flora.

In the description of genera and species the type description has been generally followed and only essential references for each species have been cited. The description is followed by information on habitat and distribution in the region.

A few new species and forms have been described by the author towards the end of the monograph. There is an extensive bibliography, divided into two parts—General Bibliography and Bibliography of Indian Blue-Green Algae. The Index is also given in two parts, separately for the General and the Systematic parts.

This monograph should prove ideal as a text book on blue-green algae, particularly at the post-graduate level. It should also prove very valuable to

advanced research workers, Public Health Institutions, Agriculture and Fisheries' Departments.

It is copiously illustrated and is printed on art paper. The printing and get-up are of a very high standard. —R. S. C.

Instructions to Authors

Articles of agricultural interest are accepted for publication in the *Indian Journal of Agricultural Science*. The manuscript should be neatly typed (double space), and sent in duplicate to the Editor (Research), Indian Council of Agricultural Research, Krishi Bhavan, New Delhi. The articles should not exceed 20 typed pages. Preference will be given to papers containing results of original research. Normally, only one paper by the same author will appear in a single number.

Every paper is scrutinized by a referee. The author is subsequently asked to revise the paper in accordance with the referee's or editor's comments.

Proofs are sent to authors for correction, and these should be returned *within seven days of the receipt*. Alterations in the proofs leading to an additional payment to the press, will not normally be accepted.

Articles sent for publication should not have been published elsewhere and should be exclusive for this journal. Each article should have a brief summary limited to not more than 350 words.

In the case of botanical and zoological names, the International Rules of Botanical/Zoological Nomenclature should be followed. Generic and specific names should be underlined in the manuscript. In the case of a plant/animal, which is not widely known, the name of the family should be given in brackets.

References to literature, arranged alphabetically according to authors' names, should be placed at the end of the article, the various references to each author being arranged chronologically. Each reference should contain the name of the author (with initials), the year of publication, subject title, the abbreviated title of the publication, volume, and page numbers. A sample citation is as follows: RANDHAWA, M. S. 1936. Marked periodicity in reproduction of the Punjab fresh-water algae. *Proc. Indian Acad. Sci.*, B. **3**: 401-409.

In the text, the reference should be indicated by the author's name, followed by the year of publication enclosed in brackets, e.g., (Moore, 1951). When the author's name occurs in the text, the year of publication alone need be given in brackets, e.g., Kashyap (1929).

Illustrations should be limited to minimum considered necessary, and should be made with pen and indelible India ink for reproduction. Photographs should be on glossy paper and at least of cabinet size.

Twentyfive off-prints, without covers, are supplied free to the author. Extra copies, if required, should be ordered while returning the proofs. These will have to be paid for by the authors.

Job Press Private Limited, Kanpur.